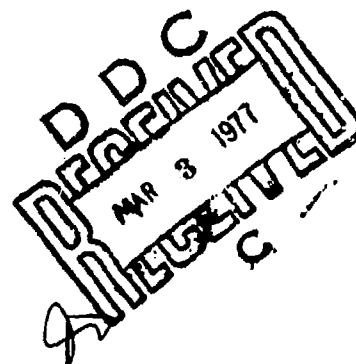ADA036327

TECHNICAL REPORT RC-77-3

US ARMY TOTAL RISK ASSESSING COST
ESTIMATE (TRACE) GUIDELINES

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31 December 1976

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35809

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This report describes the background, logic, and purpose of the TRACE concept. Some basic methodologies for conducting TRACE analyses are described and illustrated. Procedures to be followed for obtaining risk capital are also described and illustrated.

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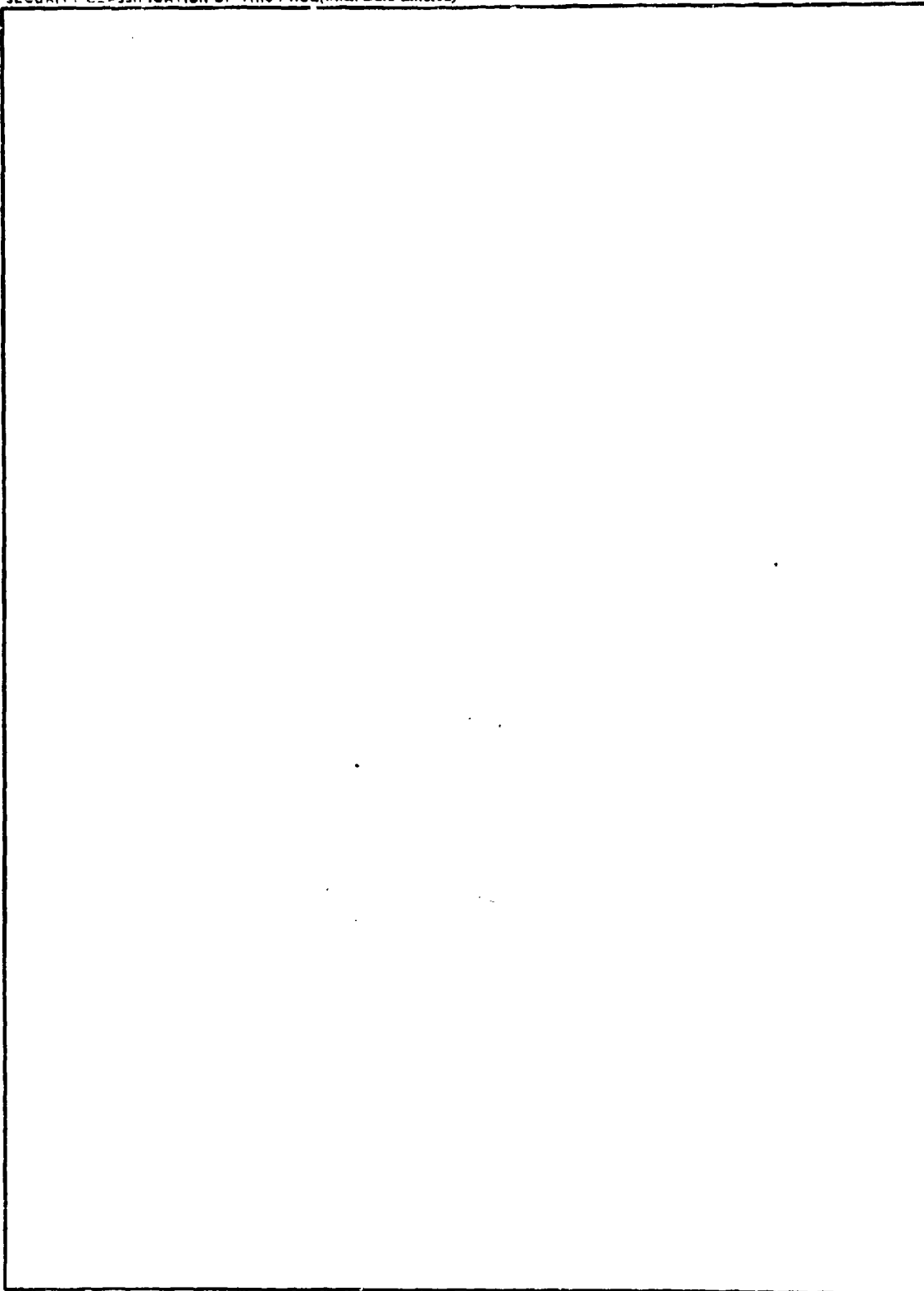
FOREWORD

This document was prepared for the US Army by John M. Cockerham
and Associates, Inc., under contract DAAH01-76-C-1088. Its
objective is to provide assistance to both project managers and
their supporting analysts. A management reading guide has been
furnished to indicate those sections of the report that should
be important to managers.

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MANAGEMENT READING GUIDE

Management Reading Guide

GLOSSARY OF SYMBOLS

I. General

AEL - Adjusted Expected Loss

DA - Department of the Army

DAMA-PPR - Deputy Chief of Staff for Research, Development and Acquisition, Department of the Army

DRCDE-P-C - Directorate for Development and Engineering, Army Development and Readiness Command

FY - Fiscal Year

OSD - Office Secretary of Defense

PM - Project Manager

PQT-G/C - Prototype Qualification Testing - Government/Contractor

RC - Risk Capital

TRACE - Total Risk Assessing Cost Estimate

II. Mathematical

AEL - Adjusted Expected Loss: The probability point of occurrence corresponding to full funding. General: Any mathematical adjustment to expected value logic of funding that is proportional to the probability of occurrence.

AEL_i - Adjusted Expected Loss for the ith element

C - Composite of fixed (a) and variable cost (b) over specified time (t)

   a - fixed cost ($)
   b - variable cost ($/MN)
   t - time (MN)

C_{A_i} - TYPE A Cost for the ith Element

C_{B_i} - TYPE B Cost for the ith Element

$E(C_1)$ – Expected value of a cost overrun for FY1 given an overrun occurs

C_1 – Random cost variable for FY1, given the actual project cost exceeds the FY1 budget

$f(C_1)$ – Cost density function

$d(C_1)$ – Differential cost

$E(1_i)$ – Expected loss for the ith fiscal year (product of the expected cost $E(C_i)$ and the probability that an overrun actually occurs.)

$\%E(1_i)$ – Percentage of the expected loss for the ith fiscal year to the total expected loss for all fiscal years

$E(1s)$ – Total expected schedule loss

$E(1s)_i$ – Total expected schedule loss __through__ the ith fiscal year

$f(x)$ – Total project cost density function

$1s_i$ – Probabilistic schedule loss associated with the ith element

$P(A)$ – Probability of event A occurring

$P(A_i)$ – Probability of event A occurring for the ith element

$P(\bar{A})$ – Probability of event A not occurring

$P(B)$ – Probability of event B occurring

$P(B_i)$ – Probability of event B occurring for the ith element

$P(B|A)$ – Probability of event B occurring, given event A has occurred

$P(B|\bar{A})$ – Probability of event B occurring, given event A did not occur

RC/FY – Risk Capital per fiscal year

RC/FY_i – Risk capital for the ith fiscal year

TYPE A – Refers to a problem and cost of the problem associated with a particular element/milestone of a project

TYPE B – Refers to the cost impact on other elements/milestones or to the entire project due to the occurrence of a TYPE A problem

X_i – Project budget for the ith fiscal year

TERMINOLOGY

Reference Page vi

TRACE (Total Risk Assessing Cost Estimate) - Refers to the total RDT&E project
cost which is the sum of the Baseline Cost Estimate and the Risk Capital.

BASELINE COST ESTIMATE (BCE) - The project cost, sometimes referred to as the
engineering cost estimate, characterized by the general method of determining project
cost against a fixed schedule for all planned activities.

RISK CAPITAL (RC) - Refers to the total project monies retained at DA and is mathematically
the difference between TRACE and the BCE.

RISK CAPITAL/FISCAL YEAR (RC/FY) - The project risk capital for a given fiscal year.

TRACE TERMINOLOGY
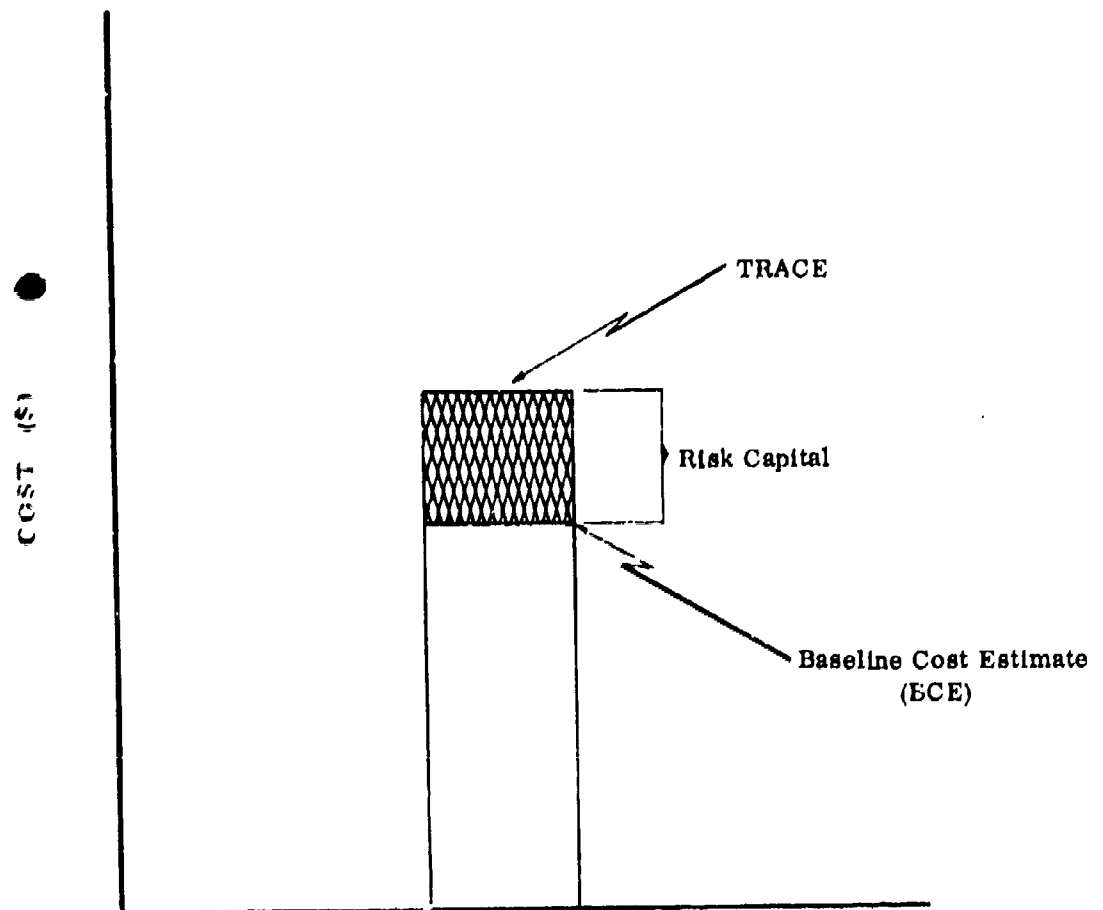
SFCTION 1

INTRODUCTION TO THE TRACE CONCEPT

1.1   Background

The TRACE concept deals with project RDT&E budget planning under conditions

of risk/uncertainty and the allocation of the monies to minimize cost growth resulting from

additional expected costs. If the costs are expected then why not plan money to cover the

costs using the standard budgeting approach? The costs are expected, but they are probabilistic

as to when they will occur and how much they will be. Therefore, it is impossible, without

grossly overbudgeting, to plan fixed dollars at a fixed time to cover unknown expenditures of

undetermined amounts. Though the situation appears hopeless, there are ways to scientifi-

cally cope with the problem. Simply because something is uncertain does not mean it should

be ignored. On the contrary, the uncertainty should be analyzed for the likelihood of problem

occurrences and the impact of problems. This will define risks. Now, If we can determine

approximately when the risks will occur, then we can begin to logically manage the project

uncertainties to minimize the losses. How does private enterprise do it? They follow the

general approach described below:

1.   Plan and cost projects carefully with particular attention to schedules.

2.   Conduct detailed analyses of all project risks and when they will likely occur.

3.   Budget against all planned expenditures. This usually includes a small
        percentage for uncertainties. (K-factor logic)

4.   Develop a strategy to cope with the probabilistic expenditures beyond the
        budgeted amount.

In (4.) above, there are several strategies that may be used, but the one analogous to the

TRACE concept is the "line of credit". Here management knows that during a risky portion

of the project there is a fixed amount of money that can be immediately acquired to meet

adverse expenditures. A "line of credit" through the commercial banking system can be

established, managed, and used to better ensure the success of a project and to minimize

problematic costs. Usually, such business adversities can only be overcome by reserve

risk capital or a credit line. In either event the money can be obtained quickly, when needed,

to avoid even greater losses due to project incompletion.

The system that allows the commerical section to manage such uncertainties is the

commercial banking system. Regardless of management science tools, there must be a

system that allows management the flexibility to manage. The defense sector has never had

any system that allowed a project manager an effective means to cope with uncertaintie ;.

The TRACE concept gives the project manager the flexibility, authority, and means to

effectively manage through all types of adversities.

Analogous to the commercial banking system there is a system that allows the TRACE

concept to work. The operational mechanics of this system are discussed in Section 2.

The system has certain rules and requirements, and has the necessary "checks and

balances" to ensure continuing operation.

With the knowledge of the operational system, the manager should be mainly concerned

with the TRACE methodology used on his project. These guidelines address various

methodologies and thought processes that are generally appropriate for TRACE analyses.

For the TRACE concept to work, management must understand the logic associated with

the methodology that is used and there can be no communication gap between the manager

and analyst. TRACE analyses are tied tco closely to the success of the project and the

mistakes in this work are too costly for managers and analysts to isolate one another.

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For this reason, these guidelines have been prepared for the manager and analyst in an attempt to bridge any communication gap that may exist.

1.2   Methodology Overview

The numerous methods for determining risk capital and its allocation preclude
the possibility of a totally comprehensive discussion. The objective of this document
is to guide the manager and analyst with the intent of the thought process. In no way is
this document meant to constrain creativity or thwart the development of new and
improved methodologies.

1.2.1 Risk Capital

At the outset, it is acknowledged there is no precise answer to how much money
should be allocated to avoid excessive risk tak'ng. To ignore uncertainties and expected
problems is unrealistic, yet to fund at a level to cover all risks is equally unrealistic.
Therefore, as in any business, the objective is to strike a reasonable balance between
risks and investment capital (RDT&E funds).

What is "reasonable" and will Congress and top defense managers accept such a
value? Regardless of acceptance, one can only ask for a reasonable estimate. This is
due to the inherent humanistic aspect of risk taking preferences with reaepect to monetary
investments. For example, individual (A) may invest in high risk/high return stock wher
another (B) will invest the same sum in low risk/low return stock. Of course, (A)
thinks (B) is conservative and (B) thinks (A) is extravagant and both think the other
foolish. However, neither is wrong provided they did not violate their own preference
for risk taking. This is true regardless of the outcome! Clearly, risk versus investmen

is individualistic and any particular decision by one man or one group is precisely wrong
when viewed by any other man or group. This is also true with value decisions con-
cerning the investment capital for weapon systems. Therefore, the guidelines have
addressed methodologies that will assist in establishing a "reasonable balance between
risks and investment capital (RDT&E funds)".

Quantitative Approaches:

Two general approaches for quantifying cost uncertainties are,

1. Probabilistic Network Modeling

2. Risk Tabulation

The general aspects, advantages and disadvantages of each general approach are

discussed below:

Probabilistic Network Modeling: This is a form of modeling where there is generally
an attempt to interrelate cost and schedule. The models are schedule oriented in
that cost is usually a function of the schedules of the activities comprising the project.
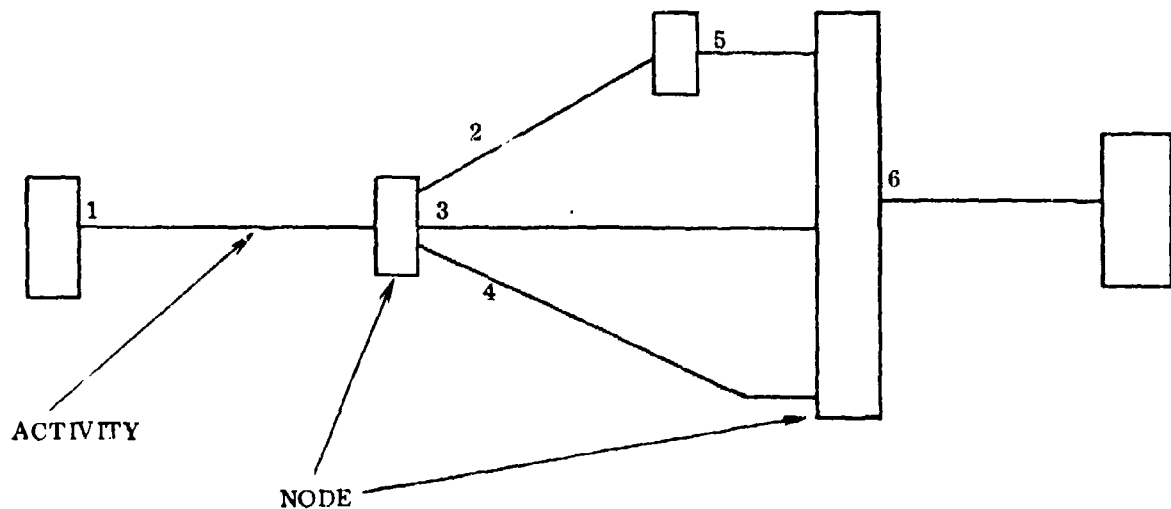
Figure 1.1

The nodes indicate the logic describing the relationship between activities. For example, in Figure 1.1, activities 2, 3 and 4 can start only after activity 1 is completed. The activities carry cost and schedule information, often where cost is a linear function of schedule.

$$C = a + bt$$

Total Cost ($) = Fixed Cost ($) + Variable Cost ($/MN) x Time (MN)

* Fixed Cost ($) - one time expenditures (i.e. materials, equipment purchases, sub-contracts, etc.)

* Variable Cost ($/MN) - recurring cost or the amount of money spent on a monthly basis (or any time unit). (i.e. labor, rentals, progress paid contracts, etc.)

Time (MN) - activity duration in months (or other time unit compatible with variable cost unit)

For any project activity, uncertainty may exist with the fixed cost (a), the variable cost (b) and the time (t). If this uncertainty can be expressed, then a Monte Carlo simulation can handle the calculation of each variable. An example for Activity 1 is given below. Note: The uniform and triangular distributions are examples. Other forms are also used in practice.

Activity #1

Fixed Cost (a)
K$

60   85
UNIFORM DISTRIBUTION
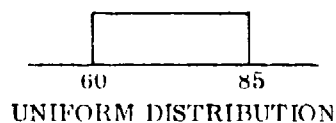
Input data reflect the fixed cost could be as low as $60 K or as high as $85 K and it is equally likely to be any value between.

Variable Cost (b)
K$/MN
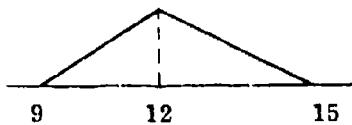
TRIANGULAR DISTRIBUTION

Input data reflect the variable cost will most likely be around $12 K/MN, but could be as low as $9 K/MN or as high as $15 K/MN with diminishing possibilities toward the extremes.

Time (t)
MN
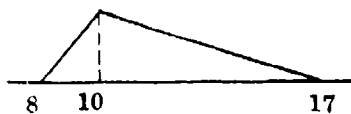
TRIANGULAR DISTRIBUTION

Input data reflect the time for Activity 1 cannot be less than 8 MN, will most likely be around 10 MN and could be as much as 17 MN, with diminishing possibilities toward the extremes.

The Monte Carlo simulation technique will sample each input distribution and perform the calculation, $C = a + bt$, many times until a statistical distribution can be determined for the cost of Activity 1. For the above example a Monte Carlo simulation with 500 samplings yielded the cost distribution shown in Figure 1.2, page 8.

Computer aided, the Monte Carlo simulation technique can be used to combine probabilistic cost of any number of activities according to the node logic of the network. For an example, see Figure 1.3, page 9. The output of the simulation is in the form of statistical distributions and is structured to assist in the decisions concerning TRACE and risk capital. The output is based on the probabilistic cost of all planned and contingency activities. The total of these costs for the entire project is needed to determine the TRACE and total risk capital value.

Figure 1.2

MONTE CARLO SIMULATION

COST DISTRIBUTION FOR ACTIVITY #1   ($K)
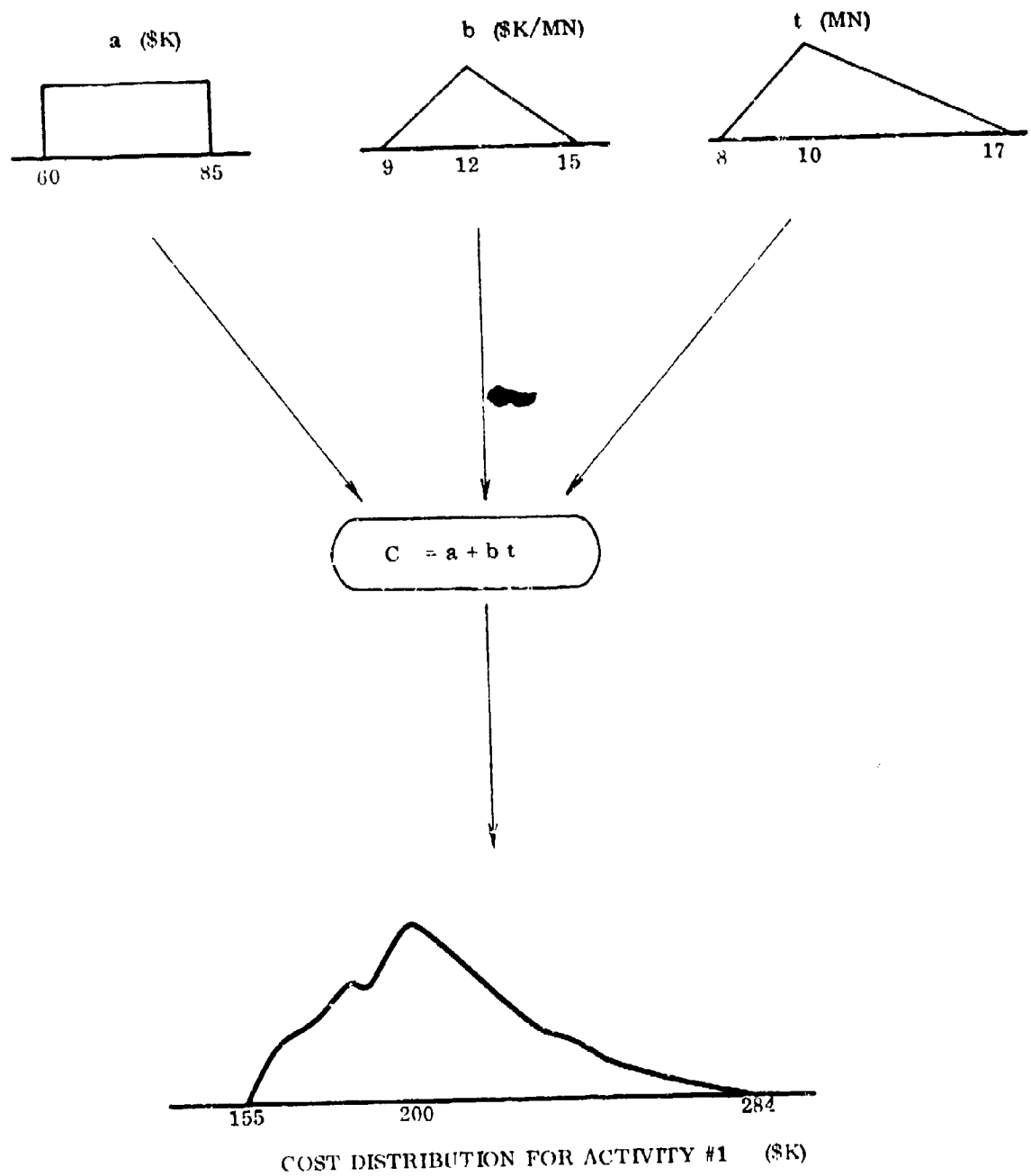
Figure 1.3

Monte Carlo Simulation

of Multiple Activities
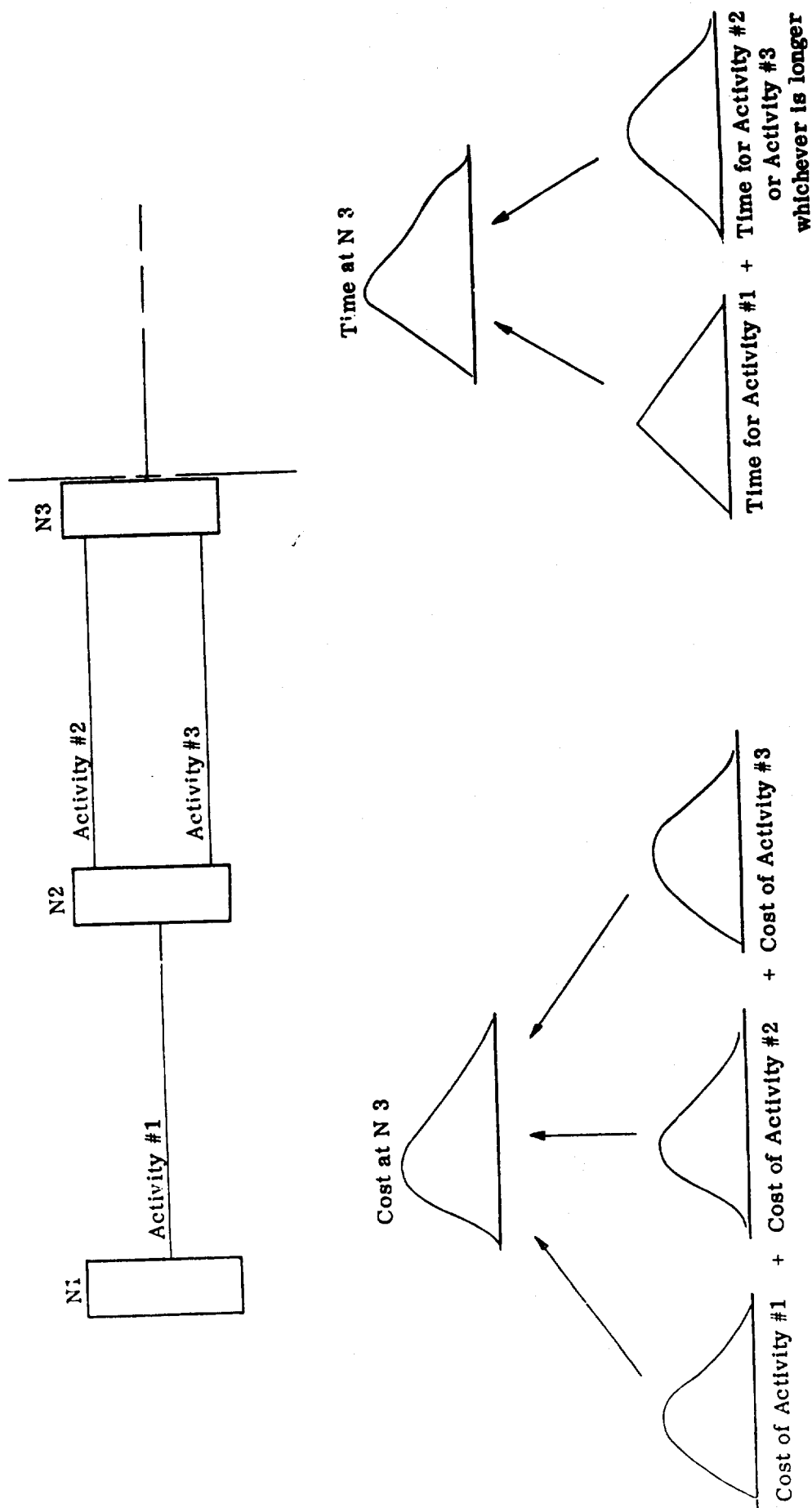
In order to allocate the TRACE and risk capital by fiscal year, probabilistic cost information by fiscal year is needed or is, at least, helpful. The allocation of the risk capital money is made in a manner to reduce future expected losses. That is, more risk capital is provided in the years where the uncertainty and cost impact are the greatest. This is in contrast to the logic of allocating in proportion to total dollars each fiscal year (e.g. 10% risk capital for each fiscal year).

Advantages of Network Modeling:

1. The cost uncertainty associated with the interaction of the activity schedules and their uncertainty is accounted for in the total cost. Note: Preliminary studies indicate that 50% - 90% of the total cost uncertainty is a direct result of schedule uncertainty.

2. There is maximum flexibility with the form and collection of the output data for decision-making purposes.

3. When maintained on a continuing basis, the network model can be operated many times, quickly and inexpensively.

4. The network can be used to estimate the Basic Engineering Cost (BCE) using fixed schedules.

5. The network can be used to track and control as well as predict a project's cost and schedule.

Disadvantages of Network Modeling:

1. A high analytical skill level is required to build the network and collect the data. The output of the model is very sensitive to the management logic associated with the project activities. Seemingly insignificant assumptions can totally negate the usefulness of the output data. The modeling difficulty coupled with the sensitivity demand experienced and skillful analysts.

2. The selection of an appropriate network model is difficult. This is due to the numerous network management models available with a wide variation in the

quality of the programs (i.e. usefulness, flexibility, operational assumptions and internal operations).

Note to Management: The manager should be concerned about the network model used on his project. Presently, there are no formal screening or evaluation procedures for computer programs. Therefore, the manager should seek the recommendation of a qualified TRACE analyst. In addition, management should stay involved with the analysis due to the often experienced difficulty of recognizing the quality of the output data. Typically, computer output information is impressive in appearance and quantity. Management's blessings on the output of a network model should result from careful study and scrutiny of the analysis.

3. Cost as a linear function of time is not traditionally used, is not totally consistent with the breakdown structure, and is not easily comprehended.

4. The cost for network analyses on major projects is initially high and requires about three months before any output data is generated. This initial disadvantage is offset by savings if the project uses the network model on a long-term basis.

1.2.2 Risk Tabulation

In this approach for quantifying cost uncertainties, each activity or hardware element of a project is addressed. In addition, all other potential problems are itemized, and in particular, those related to schedule risk. A tabular type data entry is sufficient for this analysis. The details of this approach are discussed in Section 4, page 40, but in general the analysis is based upon the calculation of the expected loss associated with each element. The total expected loss combined with appropriate decision logic determines the total risk capital. The fiscal year allocation is based upon when the cost impact will likely occur.

Advantages of Tabulating Risks:

1. The analysis does not require a high analytical skill level.

2. The analysis can be performed quickly and inexpensively in comparison to computer modeling.

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3. The analysis can easily be comprehended since complicated interrelations are avoided.

4. The quality of the analysis can be easily ascertained by management due to the openness and simplicity of the analysis. There are no hidden assumptions or modeling errors.

Disadvantages of Tabulating Risks:

1. This type of analysis does not fully address the interrelationships between program elements, or the expected savings from the early completion of program activities. These omissions adversely affect the quality of risk capital determination and the allocation of the monies by fiscal year. This disadvantage is more pronounced on the larger, more complicated weapon system projects.

2. The simplicity of the analysis often encourages misinterpretations. This is largely due to the intuitive, rather than statistical, use of the expected loss term. Tying the expected loss calculations directly to WBS elements implies that the risk capital allocated for each element will be spent against that element to reduce or eliminate the risk. This is totally false in that we do not know exactly where or how much will be spent against uncertainties. We do know it will never be the amount calculated as the expected loss. Therefore, the expected loss term is rather meaningless after its statistical use in the determination and allocation of risk capital.

3. The flexibility of the analysis and the output is extremely limited. That is, any significant changes in a project's schedule or requirements would likely dictate a completely new analysis. At the time these studies are normally performed there are many program changes which could preclude this approach from being responsive.

4. There is no indication as to the total program risk. For example, in the networking approach, the total dollars are based upon a probability (50/50, 60/40, etc.) of successful completion of the total project.

1.2.3 Guidelines on Selecting the Approach

The network modeling approach should be used on all projects where it is not

prohibitive due to cost, schedule, analytical expertise or computer system and program

availability. The exceptions are:

1. When a project is early in the conceptual phase and a management plan does not
   exist to the extent that a credible model can be developed and/or data collected.

2. When a project's management plan is of such obvious simplicity that the
   interrelationships can be properly addressed through itemizing the risks.

3. When the project manager does not relate to the network approach and desires
   to use a different approach. (This is allowable since the project manager bears
   the full responsibility of the project and all studies contributing to the support
   of the project.)

SECTION 2

OPERATIONAL MECHANICS

2.1   Operational Flow (Reference Figure 2.1, page 15)

The referenced flow chart pictorially describes the operational mechanics of the TRACE concept. The flow describes the process for the initial and subsequent determinations of the total risk capital (RC) and the FY allocations (RC/FY) and the process for release of the RC/FY funds. The following discussion addresses each aspect of the flow chart.

The determination of the initial values for the total risk capital and the fiscal year allocations of the monies is the responsibility of the respective project offices. The determination may be made using one of the methodologies described in this document or a different methodology at the discretion of the project manager. In any event, the analysis and logic must be well documented as appropriate to support a formal review and approval process. The formal documentation should address the following: (for details reference Annex A)

1. Results (Recommended TRACE & Risk Capital)

2. Methodology

3. Cost Omissions

4. Significant Assumptions

5. Pertinent Discussion (Addressing the analysis, allocation by fiscal year, logic, significant points or findings)

6. Alternatives (Address only the viable alternatives, if any, and only to the depth necessary to provide essential decision information)

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Figure 2.1

OPERATIONAL FLOW CHART

RISK CAPITAL REQUEST

BUDGET ADJUSTMENT REQUEST
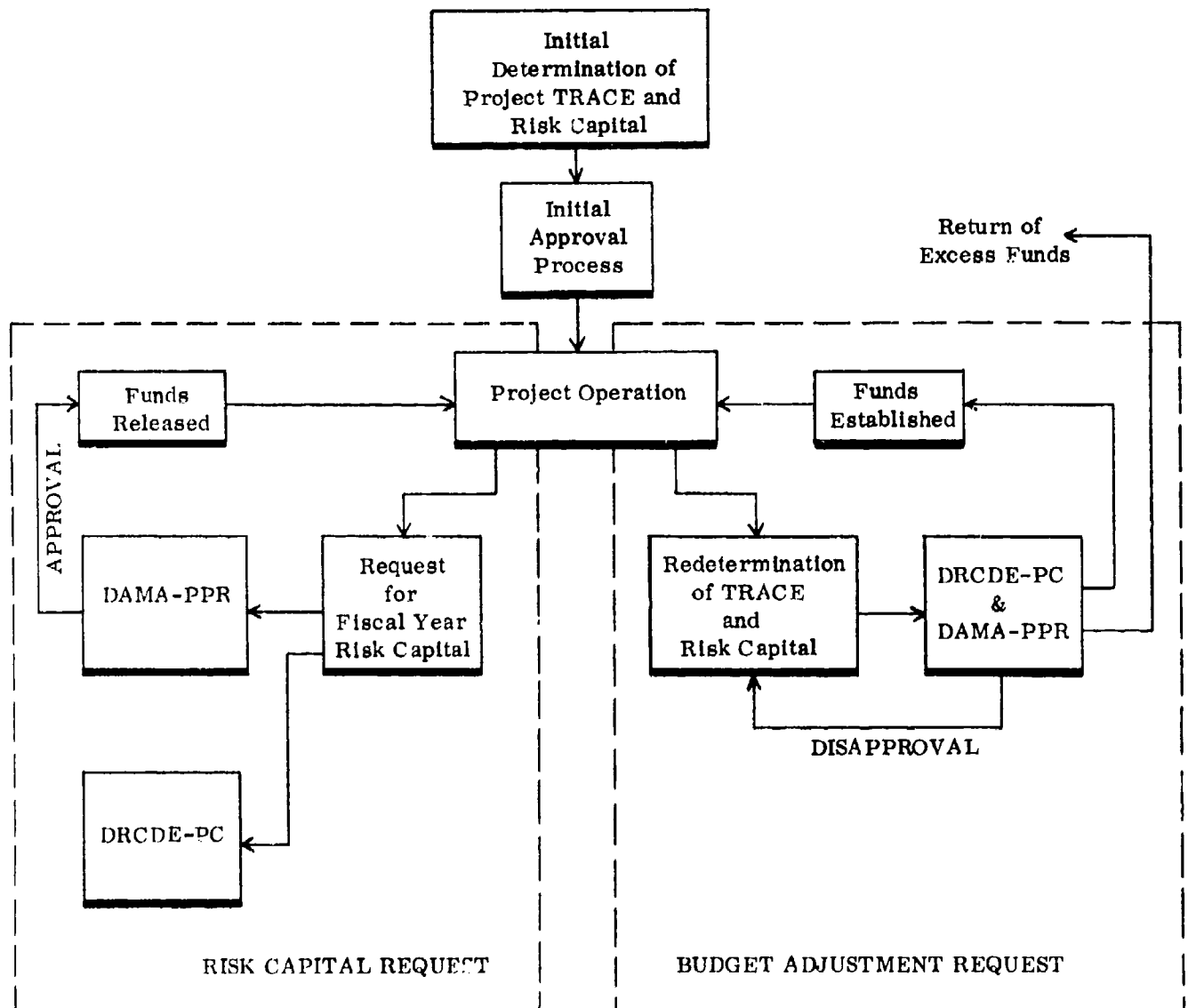
The initial approval of the TRACE and the allocation by fiscal year will follow the same process through DA and Congressional levels as any budget request. As a result of the approval process, a TRACE determination will be made. A project's total risk capital and its FY allocation may be altered during this process.

> Note to Management: The first approval process is probably the most important and an extra effort on this analysis and the documentation is encouraged. To later change the total TRACE dollars upward is a difficult task. However, there is a built-in flexibility for trade-offs between fiscal years within the total TRACE dollars.

After the TRACE is approved, uninterrupted project operation with those funds can begin. The project manager need be concerned only with the process of getting the funds and with the process of changing the funding levels. These two operations, "Risk Capital Request" and "Budget Adjustment Request", are described below.

2.1.1 Risk Capital Request

For the project manager to receive all or any portion of the approved risk capital allocation for the current operational fiscal year, a brief request must be sent to Deputy Chief of Staff for Research, Development and Acquisition (DAMA-PPR) with an information copy to Directorate for Development and Engineering (DRCDE-PC). (Reference Annex B, Risk Capital Request.) The funds will be released for project use in a maximum of four (4) working days from receipt of the request. The project is required to send a follow-up justification to DRCDD-PC within thirty (30) working days of the original request. (Reference Annex B, Risk Capital Justification.)

DRCDE-PC is the point of contact and action agency at DARCOM. Their responsibilities regarding FY risk capital requests are to:

1. Maintain a record of all requests.

2. Ensure the operational process is followed.

3. Ensure the risk capital funds are being generally used as intended.

DAMA-PPR is the DA staff point of contact and the organization responsible for the release of the risk capital to the project office. Their responsibilities regarding risk capital requests are to:

1. .Ensure the Risk Capital Request basically supports the release of funds.

2. Ensure that the funds are made available to the project office in a maximum of four (4) working days.

3. Make recommendations to the DCSRDA concerning action to be taken for projects that have violated the purpose and use of the risk capital funds.

   Note to Management: The DCSRDA will not exercise authority to deny allocated risk capital to project offices, provided the minimal requirements in the request are met. In other words, the project manager will get all or any portion of the approved fiscal year risk capital for the asking. This gives the PM maximum flexibility with the money virtually at his fingertips. Only in unusual cases or where a PM misuses the funds will DAMA-PPR require advance formal justification and/or detailed accounting of the risk capital, and/or other measures as appropriate.

2.1.2 Budget Adjustments Request

To increase the approved TRACE requires a detailed redetermination of TRACE and Risk Capital with DA and Congressional approval. However, if there are downward changes in the TRACE or changes in the distribution of the risk capital between fiscal

years, then the request requires justification but the approval process is totally within DA. The project manager is encouraged to evaluate the project's risk capital requirement each year. This seems prudent since the FY risk capital was planned against uncertainties, and with one year of the uncertainties removed, additional knowledge is available for a better allocation of the monies.

Although advisable, the redetermination of the total and FY risk capital need not follow the same methodology as the initial determination; however, appropriate analysis and logic to support a formal request is required. The request is fowarded to DAMA-PPR through DRCDE-PC. Approval/disapproval will require a maximum of 15 work-days upon receipt of the request. With approval, the funds will be established according to the request or a compromise thereof and any excess risk capital funds, not carried forward, will be returned to DA.

> Note to Management: In the past, the idea of returning any money to DA or Congress on a weapon system project was deemed undesirable and an indication of management's inability to accurately estimate costs and budgets. THIS IDEA IS CHANGING. The mere recognition of risk capital implies a recognition of uncertainty. When all or a portion of the risk capital is not needed, then it should be returned to DA. Only when management has grossly overbudgeted for planned expenditures would the return of funds warrant any unfavorable response. To manage through the uncertainty without the need for the risk capital would truly be remarkable and the management should be rewarded. Furthermore, with the successfulness of the TRACE concept proven, Congress may allow DA the discretion to reinvest the excess funds into other projects. Certainly, this is more effective than the widespread expenditure of year-end project funds simply because the funds are available.

SECTION 3

TRACE NETWORK MODELING

3.1   Methodology for Network Modeling Approach

There are numerous network models available. The quality and capability

of the models vary greatly. It is not possible to discuss all of the models;

therefore, the discussion will address the application of a particular model. The

model was used for a TRACE analysis on a project at the U.S. Army Missile Command.

First, the methodology associated with the network model is discussed. Secondly,

an example TRACE study is presented for the purpose of conveying the thought process

of the analysis.

The development of a network of the project activities is the first step. The

network displays all interrelationships between project activities. The activities

consume resources (dollars and time) and are initiated and terminated according to the

management logic expressed at the nodes.

> Note to Analyst: Node logic varies between network programs. In selecting
> a program the analyst should study the node logic carefully. The logic must
> be sufficiently sophisticated to adequately model the project.

The statistical outputs used in the TRACE analysis are:

a. Total cost frequency distribution
b. Total cumulative cost frequency distribution
c. Cost distribution per fiscal year

TRACE Determination

The TRACE point (total probabilistic cost of the project) is simply the point

on the distribution corresponding to a desired level of risk taking. The actual risk

point determining the TRACE value is the 50/50 point unless there is justification

for deviation. The 50/50 point on the cost distribution should always be provided

in the results of a TRACE network analysis. This is for comparison purposes or

a baseline in viewing other Army projects.

It is not within the scope of this document to discuss all of the subtleties

involved with the analysis of probabilistic data. However, a brief description of

a plan of analysis is described below.

1. TRACE has been defined as the 50/50 point on the total cost distribution $f(x)$.

Therefore, the first step is to determine the 50/50 point or median (B).

Figure 3.1

TOTAL COST DISTRIBUTION
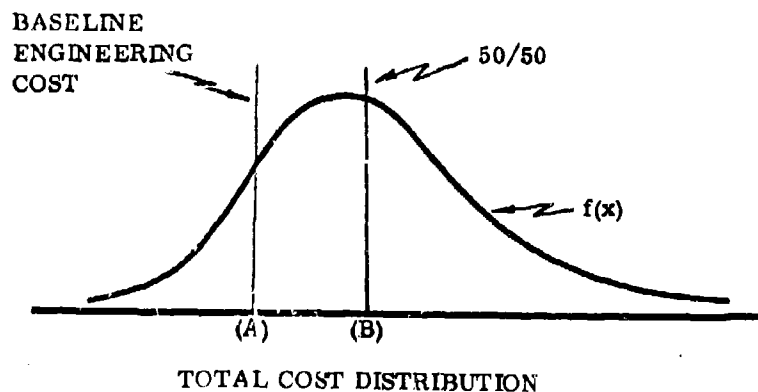
2. The baseline engineering cost (A) must be established. This is the
estimated cost of all of the planned activities and expenditures. This cost may
be determined with the network model by eliminating probabilistic and contingency
activities and using only deterministic inputs for cost and schedule. Or, the cost
may be determined by other valid means such as the Work Breakdown Structure
approach.

Figure 3.2

(A)   (B)
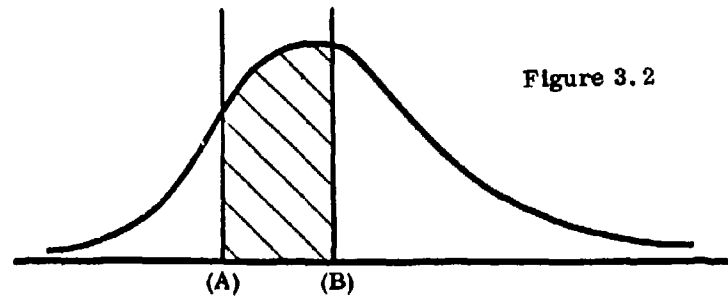
3. The risk capital is determined by subtracting (A) from (B) and is represented
by the shaded area in Figure 3.2.

The purpose of risk capital is to cover a percentage of the expected cost overrun,
provided the overrun actually occurs.

Consider the example cost distribution in Figure 3.3 for the fiscal year FY1;

Figure 3.3

FY1

x_1 $E(C_1)$
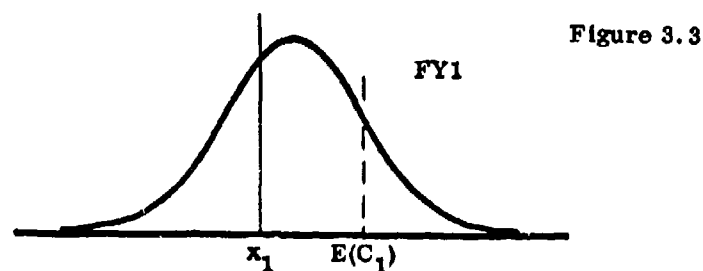
Given a cost overrun (cost greater than the engineering cost estimate (x_1), then the true cost will fall somewhere to the right of (x_1) in the shaded area. The probability of this occurrence is 1.0, therefore the shaded area under the curve must equal 1.0. This is done mathematically where the shaded area is normalized to an area of 1.0 and a new probability density function $f(c_1)$ is established. The expected value is then calculated by conventional methods.

For the new random variable the expected value is,

$$E(c_1) = \int_{x_1}^{+\infty} c_1 \, f(c_1) \, dc_1$$

Likewise the expected values $E(c_2)$, and $E(c_3)$ for FY2 and FY3 can be calculated.

$E(c_i)$ is the expected value of the cost overrun for the ith fiscal year, given there is an overrun. The expected loss for the ith fiscal year is the expected value of the overrun multiplied by the probability an overrun will actually occur.

$E(l_i) = E(c_i) \times P$ (actual cost is greater than X_i)

The percentage of the total of the expected loss for any year is determined as shown in the example calculation for FY1 given below:

$$\% \, E(l_1) = \frac{E(l_1)}{E(l_1) + E(l_2) + E(l_3)}$$

And finally, the percentage of risk capital per fiscal year,

$RC/FY1 = \% \, E(l_1) \times RC$

$RC/FY2 = \% \, E(l_2) \times RC$

$RC/FY3 = \% \, E(l_3) \times RC$

The example analysis is adequate for all known activities and contingency activities. However, the model and the analysis have neglected all of the costs of activities we know nothing about. There is no approach other than looking at the histories of similar projects and allocating a percentage of funds that will offset "cost surprises" which are sure to occur. Other known cost omissions should be addressed and handled on an exception basis.

3.2   Project X Example TRACE Analysis

The following example is taken from an actual TRACE analysis performed on a system at the Army Missile Command.   This example includes the network model, data inputs, TRACE and risk capital outputs, and the documentation for the budget request.   The example is not regulatory, but rather provided as a guide to demonstrate an acceptable thought process for a TRACE analysis.

Reference the following information:

1. Project X TRACE Network (Figure 3.4 page 27).

The network represents all RDT&E project activities and their interrelationships. The detail of the network is a matter of judgement.   However, the main considerations are:

a. The model should sufficiently demonstrate the management philosophy and interrelationship between activities.

b. The costs must be properly accumulated for the total project and for each fiscal year.

2. Project X Cost and Schedule Input Data, Annex C.

3. Data Output and Analysis.

The output for schedule and joint cost/schedule risk has been omitted for brevity.   The essential output data for a TRACE analysis are as follows:

		Page
a.	Cost distribution for all activities	29
b.	Cumulative cost distribution for all activities	30
c.	Cost distributions and cumulative cost distributions for each fiscal year	31-38

TRACE at the 50/50 risk point is read directly from the cumulative cost distribution

as $167.65M. Other risk points may also be determined from this distribution.

The risk capital allocations (page 39) are performed by the computer in

accordance to the methodology discussed in Section 3.1, pages 19-23.

If this type of output or computer capability is not available, then the analyst

will have to use an alternate technique to allocate the total risk capital funds by fiscal

year.

Note to Analyst: As a suggestion in this area, the analyst may combine the network
and risk tabulation approaches to assist in FY allocations. The network
can be used to determine the total risk capital and tabulation of the significant
project risks to determine the allocation. In addition, some networking
programs provide data at milestones which would prove useful if the output
were obtained at milestones falling close to fiscal year ends.

10/1/70

- ADMINISTRATION, CONFIG MGT, SYS SUPPORT
- ENGINEERING SUPPORT
- PROPULSION SYSTEM PRODUCTION
- MOTOR PRODUCIBILITY TESTS — MOTOR QUAL (PHASE I) — MOTOR QUAL (PHASE II)
- TARGETS PROCUREMENT
- EUROPEAN DELIVERIES — JOINT TEST
- TELEMETRY DEV & SUPPORT — TELEMETRY EFFORT
- EUROPEAN KITS — EUROPEAN KITS ENG SUPPORT
- FWD SEC & TOOLS & TEST EQUIP — FWD SEC COMP OF TOOLS & EQUIP — 40 MISSILES — 67 MISSILES
- MANUF & INTEG OF MSL ROUND (4) — MANUF & INTEG (16)
- ASSY FWD SEC & CHECKOUT — FWD SEC QUAL — ASSY QUAL RBD & C.O. — ROUND QUAL
- ELECTRONIC S & A — CON'T ELEC S & A
- IMPACT FUEL
- MISSILE AFT SEC ENGR & DELIVERY (1ST UNIT) — AFT SEC & TOOL FAB ASSY & INTG — CON'T AFT & LAUNCH TUBE (18) — CON'T AFT & LAUNCH TUBE (50) — CON'T AFT & LAUNCH (67)
- LAUNCH TUBE DEL (1ST UNIT) — N UNITS FOR JOINT TESTS
- SPECIAL TOOLS & TEST EQUIPMENT
- WARHEAD ENG QUAL & DEL (1ST UNIT) — WARHEAD FAB, ASSY & DEL (75) — CON'T WARHEAD (20) — CON'T WARHEAD (12)
- SAFETY TESTS
- PROG MGT ENGR PUBS TECH DATA & TEST SUPPORT
- GOV'T SUPPORT (ARMCOM)
- MANUALS, PROVISIONING, ENG
- PROTO FAB ASSEMBLY & CO (2) + QUEER — FAB ASSY & CO — DUMMY
- DELIVER 2 UNITS — DELIVER 2 UNITS
- SPECIAL TOOLS & TEST EQUIPMENT — INTEG SUPPORT — CON'T INTEG SUPPORT
- COMPLETE F. U. INTEG & TEST UNITS 3 & 4
- TRAINING & ROAD TEST
- COMMUNICATION EQUIP (GFE) — F. U. INTEG & TEST UNITS 1 & 2 — DELIVER UNITS 1 & 2
- FIRE UNIT INTEG SUPPORT
- LAUNCH & GUIDANCE CONTROL FAB ASSEMBLY & CHECKOUT — CON'T LAUNCH & GUID
- 1ST DELIVERY
- AUX EQUIP FAB ASSEMBLY & CO — CON'T AUX EQUIP
- 1ST DELIVERY
- CABIN FAB ASSEMBLY & CO — CON'T CABIN — PEP
- 1ST DELIVERY
- TURRET FAB ASSEMBLY & CO — TURRET CON'T
- 1ST DELIVERY
- HFF PROCUREMENT
- SEARCH RADAR / TRACK RADAR / ELECTRO OPTICAL — ENG MANUF & TEST — 1ST UNIT
- CON'T ENGR MANUF & TEST — (FROM N37 ONLY) SUPPORT INTEG
- PEP
- UNITS PROCUREMENT DELIVERY & CHECKOUT CLEAR WEATHER (No. 1 SET)
- UNITS PROCUREMENT DELIVERY & CHECKOUT CLEAR WEATHER (No. 2 SET)
- UNITS OPERATOR PROFICIENCY TRAINER No. 1
- UNITS OPERATOR PROFICIENCY TRAINER No. 2
- UNITS TRACK RADAR
- ILS
- ILS SUPPORT FMTS — CON'T SHELTER INSTALLATION FM'S
- SYSTEM DESIGN FMTS — FAB & ASSEMBLY (PHASE I) — INTEG & C. O. UNIT 1 FMTS — SHELTER INSTALL UNIT 1 FMTS — INTEG & CHECKOUT UNIT FMTS — ENVIRONMENTAL TESTS FMTS
- HARDWARE DESIGN FMTS
- SPARES — SPARES (CON'T)
- GFD DATA

PROJECT X TRACE NETWORK

Figure 3.5

Cost Distribution for All Activities

```
.248  M
      I
 .223 I
      I
 .198 I
      I
 .174 I
      I
 .149 I
      I
 .124 I
      I
 .099 I
      I
 .074 I
      I
 .050 I
      I
 .025 I
      I
0.000 +I----I----I----I----I----I----I----I----I----I
  153557.75   161023.41   164549.06   168074.71   171540.37   175006.02   178531.67   182057.32   185522.98
       159385.58   162851.24   166296.89   169792.54   173258.19   176723.85   180279.50   183775.15   187270.80
```

TRACE   RISK   NETWORK

COST DISTRIBUTION FOR TERMINAL NODE 90
MEAN = 165552.95   STANDARD DEVIATION =   6486.55

29

Figure 3.6

Cumulative Cost Distribution for All Activities

50/50 TRACE POINT $167.65M

TRACE RISK NETWORK

COST-DISTRIBUTION FOR-TERMINAL-NODE-90
MEAN = 168653.95   STANDARD-DEVIATION = 6486.55

Figure 3.7

Cost Distribution for FY80

```
.316  ▌
      I
      I
.284  ▌
      I
      I
.253  ▌
      I
      I
.221  ▌
      I
      I
.190  ▌
      I
      I
.158  ▌
      I
      I
.126  ▌
      I
      I
.095  ▌
      I
      I
.063  ▌
      I
      I
.032  ▌
      I
      I
0.000 +I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I
      98450.87   98993.38   99535.88   100028.39  100620.90  101163.41  101705.92  102248.42  102790.93
         93722.12   99264.63   99807.14   100349.65  100892.15  101434.66  101977.17  102519.68  103062.18
```

TRACE RISK NETWORK

COST PRINTOUT FOR TIME =   12.00
MEAN = 102443.51   STANDARD DEVIATION =   713.57

PROBABILITY OF COST OVER-RUN AT TIME =   12.00 IS 1.00   AVERAGE OVER-RUN IS   2743.51

Figure 3.8

Cumulative Cost Distribution for FY80

TRACE RISK NETWORK

COST-PRINTOUT FOR TIME = 12.00
STANDARD-DEVIATION = 713.57
MEAN = 100443.51

2062 ILITY OF COST-OVER-RUN-AT-TIME = 12.00 IS 1.00 AVERAGE-OVER-RUN-IS 2743.51

Figure 3.9

Cost Distribution for FY81


```
P   .316  H
         I
         I
R   .284  H
         I
O   .252  H
         I
         I
B   .221  H
         I
         I
A   .190  H
         I
         I
B   .158  H
         I
         I
I   .126  H
         I
         I
L   .095  H
         I
         I
I   .063  H
         I
         I
T  -.032  H
         I
         I
Y  0.000  +I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I
        45192.65   46195.97   47211.27   48225.58   49239.89   50254.20   51268.50   52282.81   53297.12
           45689.81   46704.12   47718.43   48732.74   49747.04   50761.35   51775.66   52789.97   53804.27
```

TRACE RISK NETWORK

COST PRINTOUT FOR TIME = 26.00
MEAN = 49926.36   STANDARD DEVIATION = 2037.67

PROBABILITY OF COST OVER-RUN AT TIME = 26.00 IS 1.00   AVERAGE OVER-RUN IS 7226.36

Figure 3.10

Cumulative Cost Distribution FY81

```
1.000
 .900
 .800
 .700
 .600
 .500
 .400
 .300
 .200
 .100
0.000  I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I
    45182.66  46196.97  47211.27  48225.58  49239.89  50254.20  51268.50  52282.81  53297.12
       45683.81  46704.12  47718.43  48732.74  49747.04  50761.35  51775.66  52789.97  53804.27
```

COST-PRINTOUT FOR TIME = 24.38
MEAN = 49926.66   STANDARD-DEVIATION = 2037.67

TRACE RISK NETWORK

PROBABILITY-OF-COST-OVER-RUN-AT-TIME = 24.00 IS 1.00   AVERAGE-OVER-RUN-IS 7226.06

Figure 3.11

Cost Distribution for FY82

```
        10363.32   12227.60   13711.87   15396.15   17080.42   18764.74   20448.97   22133.25   23817.52
          11135.46   12869.73   14554.01   16238.28   17922.56   19606.83   21291.11   22975.38   24659.66
```

TRACE   RISK   NETWORK

COST PRINTOUT FOR TIME =   36.00
MEAN = 13320.96   STANDARD DEVIATION =   2985.15

...ITY OF COST OVER-RUN AT TIME =   36.00   IS 1.00   AVERAGE OVER-RUN IS   3320.96

Figure 3.12

Cumulative Cost Distribution
for FY82

```
+----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I
10343.32   12027.60   13711.87   15396.15   17080.42   18764.70   20448.97   22133.25   23817.52
   11185.46   12869.73   14554.01   16238.28   17922.56   19606.83   21291.11   22975.38   24659.66
```

TRACE RISK NETWORK

COST-PRINTOUT FOR TIME = 36.08
MEAN = 13520.96   STANDARD-DEVIATION = 2985.15

...ILITY-OF-COST-OVER-RUN-AT-TIME = 35.00 IS -1.00   AVERAGE-OVER-RUN-IS -3320.96

Figure 3.13

Cost Distribution for FY83

TRACE RISK NETWORK

COST PRINTOUT FOR TIME = 48.00
MEAN = 4997.79   STANDARD DEVIATION = 1868.75

OF COST OVER-RUN AT TIME = 48.00 IS 1.00   AVERAGE OVER-RUN IS 3392.79

Figure 3.14

Cumulative Cost Distribution for FY83

```
I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I
58.62   2825.81   3783.00   4740.19   5697.37   6654.56   7611.75   8568.94   9526.12
     2347.22   3304.41   4261.59   5218.78   6175.97   7133.16   8090.34   9047.53   10004.72
```

TRACE RISK NETWORK

COST-PRINTOUT-FOR-TIME = 48.60   STANDARD-DEVIATION = 1868.75
MEAN = 4997.79

OF-COST-OVER-RUN-AT-TIME = 48.60 IS 1.00   AVERAGE-OVER-RUN-IS -3397.79

RISK CAPITAL ALLOCATION VS. TRADE RISK

F Y PERIOD ENDING	BUDGET	EXPECTED LOSS	RISK CAPITAL
12.00	9770.00	2743.51	2540.49
24.00	4270.00	7226.06	6691.34
36.00	10200.00	3320.96	3075.21
48.00	1600.00	3397.79	3146.36

TOTAL-EXPECTED-LOSS= 15453.40 AT-TRACE= 16688.33 TOTAL-RISK CAPITAL= 50.00 PER-CENT

F Y PERIOD ENDING	BUDGET	EXPECTED LOSS	RISK CAPITAL
12.00	9770.00	2743.51	2971.50
24.00	4270.00	7226.06	7326.56
36.00	10200.00	3320.96	3596.93
48.00	1600.00	3397.79	3680.16

TOTAL EXPECTED LOSS= 18075.15 AT-TRACE= 16688.33 TOTAL-RISK CAPITAL= 60.00 PER-CENT

F Y PERIOD ENDING	BUDGET	EXPECTED LOSS	RISK CAPITAL
12.00	9770.00	2743.51	7250.54
24.00	4270.00	7226.06	8563.37
36.00	10200.00	3320.96	3944.75
48.00	1600.00	3397.79	4036.02

TOTAL-EXPECTED-LOSS= 16688.33 TOTAL-RISK-CAPITAL= 19922.98 AT-TRACE= 70.00 PER-CENT

F Y PERIOD ENDING	BUDGET	EXPECTED LOSS	RISK CAPITAL
12.00	9770.00	2743.51	3594.07
24.00	4270.00	7226.06	9468.31
36.00	10200.00	3320.96	4750.54
48.00	1600.00	3397.79	4451.19

TOTAL EXPECTED LOSS= 16688.33 TOTAL-RISK CAPITAL= 21862.11 AT-TRACE= 80.00 PER-CENT

SECTION 4

TRACE RISK TABULATION

4.1   Introduction

When an interactive network model is not desirable, another approach is to individually address each area of risk taking. This is largely intuitive; however, the use of some rather basic mathematical relationships will add greatly to the logic and quality of the analysis.

This discussion addresses the type of data that can be obtained and what can be done with the data to assist in establishing and allocating risk capital. A step-by-step methodology is discussed below in conjunction with an example vehicle weapon system.

4.2   TRACE Analysis of Project (Y)

1. Identify project elements for evaluation (Reference Column 1, Table 4.2, page 53).

This first step simply segregates the project into elements that can be better analyzed. The most important aspect in selecting project elements is to avoid dependencies and double counting. A project may be described by WBS elements, program milestones, functional activities or a combination thereof. Functional activities are best used with a network approach; therefore the example vehicle system is described by WBS elements and major program milestones. The approach will be to evaluate the risk and impact for each element/milestone and the impact of each element/milestone on the total project (relationship to all other elements and milestones). Only the project elements/milestones with a meaningful probability of cost overrun need be addressed.

2. Assess the probability of occurrence (P(A)) of a cost impact to each element or milestone and the amount of the cost impact. The probability value is subjective and, at best, represents a reasonable management estimate of the likelihood of the event occurring (Column 2). Table 4.1, page 42 can be used as a guide for establishing probability values.

The cost impact (Column 3) of a particular element/milestone is defined as TYPE A cost. The amount of cost impact deals only with the cost to that particular element. For example, if the power train has a problem then it will take an estimated $1.5M to correct the power train only.

3. Given a TYPE A problem has occurred, assess the probability of a cost impact to other program elements or the entire program. This type of cost impact is defined as TYPE B. The probability, mathematically speaking, is the probability of B given A or P(B A). This term is necessary in order to calculate P(B), the unconditional probability of B occurring (Column 5). Both P(A) and P(B) are needed to calculate expected loss, which is explained later in paragraph 6, page 45.

The relationship of TYPE A and TYPE B costs can vary and is worth a mathematical digression for further explanation.

Definitions:

$\qquad$ Event A: TYPE A cost impact is incurred

$\qquad$ Event B: TYPE B cost impact is incurred

Assumption: Event B cannot occur unless Event A has occurred (where TYPE A cost impact may be equal to zero.)

Therefore,

$$P(B) = P(B|A)P(A) + P(B|\bar{A})P(\bar{A})$$

Table 4.1

Probability of Occurrence Statements

Qualitative	Quantitative
1. It is as likely as not the event will occur. In other words you cannot distinguish which event is more likely.	.50 Probability or 50/50 chance
2. It is more likely for the event to occur than not. Management feels about this,	
a. Virtually Certain	.90 to 1.0
b. Strongly	.75
c. Moderately	.60
d. Only slightly	.55
3. It is more likely for the event not to occur than to occur. Management feels about this,	
a. Virtually Certain	0.0 to .10
b. Strongly	.25
c. Moderately	.40
d. Only slightly	.45

Case 1: Case 1 will be experienced where Event B occurs with certainty, given Event A has occurred.

$$P(B)=P(B|A)P(A)$$

$$P(B)=(1.0)P(A)$$

$$P(B)=P(A)$$

Example: For the suspension system there is a 60% chance of a TYPE A problem. Given the problem occurs, there is a 100% chance of a TYPE B problem.

$$P(A) = .60 \qquad P(B|A) = 1.0$$

Therefore, $P(B) = (.60)(1.0) = .60$

Case 2: Event B will probabilistically occur, given Event A has occurred.

$$P(B)=P(B|A)P(A)$$

Example: For the power train there is a 50% chance of problems (TYPE A). Given there is a problem, there is a 60% chance it will cause a program impact (TYPE B). Here,

$$P(A)=.50 \qquad P(B|A) = .60$$

Therefore, $P(B) =(.50)(.60) = .30$

4. Determine the TYPE B cost/schedule impact to the project (Column 6). The TYPE B cost is an estimate of the total cost to the project, excluding the TYPE A cost to the particular element. The schedule slippage or impact should be noted as to which elements are affected or if the total project is affected. Total program schedule slips are indicated by asterisks in Column 6. The engine, element 5, causes a .1mn schedule impact to the qualification program and is so noted. Example of TYPE B cost: If a problem is incurred with the power train, the cost

(TYPE A) to fix the power train is $1.5M and the cost (TYPE B) to the entire project is $4M and 2 months slip in the total schedule. The $4M is a result of the power train's interaction with other program elements in that system integration cannot begin until an acceptable power train has been delivered. The government must pay for contractor and government personnel during this period of non-productivity. Therefore, the indirect cost of the problem is greater than the direct cost of the problem.

5. Predict the calendar time (month and year) and corresponding fiscal year the problem will occur. The elements must be listed in ascending order according to the calendar date of problem occurrence. This information will assist in the allocation of the risk capital (Columns 7 and 8).

6. Calculate the expected loss for each element/milestone (Column 9).

Expected Loss = (Probability of a cost impact) x (Amount of the cost impact)

Since there are two types of cost or losses defined as TYPE A and TYPE B, the expected loss for any element is,

$$E(l_i) = P(A_i) \times C_{A_i} + P(B_i) \times C_{B_i}$$

Where, C_{A_i} = Cost of TYPE A for the ith element

C_{B_i} = Cost of TYPE B for the ith element

$E(l_i)$ = Expected loss (cost) for the ith element

$P(A_i)$ = Probability TYPE A impact occurs for the ith element

$P(B_i)$ = Probability TYPE B impact occurs for the ith element

Example Calculation for Power Train:

$P(A_5) = .60$ $P(B_5) = .45$

$C_{A_5} = \$1.5M$ $C_{B_5} = \$4M$

$E(l_5) = (.60)(1.5) + (.45)(4) = \$2.70M$

7. Calculate the Adjusted Expected Loss (AEL) (Column 10). The AEL term is necessary to meaningfully determine the risk capital of a project. This is due to the nature of the expected value (loss) statistic. To make credible decisions using

expected values means the actual values will approach the expected value on the long term. Expected value is a statistical term and has nothing to do with what we can really "expect" to happen in most cases. For example, consider the Initial Acceptance Test milestones. There is a 70% chance of a $6M impact to the program. The expected value (loss) is,

$$E(l_7) = (.70)(\$6M) = \$4.2M$$

If $4.2 M is planned, only two things can happen,

1. There is a $6M impact and there is not enough money

2. There is not an impact, therefore, there is too much money

If there are a great number of probabilistic occurrences of a similar magnitude in the same time frame, expected value theory would be more appropriate. Since this is not the case with most projects, then some decision logic must be applied to adjust the mathematical expressions to more realistically cope with the problem of fiscal planning. The methodology to follow does not completely eliminate the problems discussed in 1. and 2. above. However, it does provide a more stable and generally less risky scheme for budgeting purposes.

ASSUMPTION: If a manager knows a problem and cost impact is virtually certain (probability .90 to 1.0), he would budget the full amount. It is reasonable to assume this logic would hold true, at least, to the point where the manager still feels strongly (.75 probability). In other words, if some problem is very likely to occur, management must plan to have all the funds available - a percentage of the funds would not help except in certain cases where it is effective to buy time.

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The Adjusted Expected Loss (AEL) is calculated using a linear adjustment to the statistical expected loss term. The adjustment is based upon the logic that all potential cost overruns with a probability of occurrence of .75 or greater will be fully budgeted. Lesser probabilities will be proportionally adjusted using .75 as a basis.

Example Calculation for Power Train:

$$P(A_5) = .60 \qquad P(B_5) = .45$$

$$C_{A_5} = \$1.5M \qquad C_{B_5} = \$4M$$

$$E(1_5) = (.60)(1.5) + (.45)(4) = \$2.7M$$

$$AEL = (.60/.75)(1.5) + (.45/.75)(4)$$

$$AEL = (1/.75)[(.60)(1.5) + (.45)(4)]$$

$$AEL = \underline{\$3.6M}$$

To obtain the AEL from the expected loss term, one need only divide the expected loss by the AEL constant (probability point of full funding). This simple adjustment to the expected loss term yields a term that relates money to the probability of need and to a reasonable decision criterion.

Figure 4.1, page 48, graphically describes the decision criterion for the level of funding vs. the probability of problem occurrence.

Curve #1 represents expected value logic where funding is directly proportional to the probability of a problem occurrence, $Y = 100X$.

Curve #2, used in our example, shows full funding above .75 probability and proportionally less below .75 probability. For $0 \leq X \leq .75$, $Y = (100/.75)X$ and for $.75 \leq X \leq 1.0$, $Y = 100$.

Figure 4.1

Decision Criterion for Funding Level
vs.
Probability of Problem Occurrence
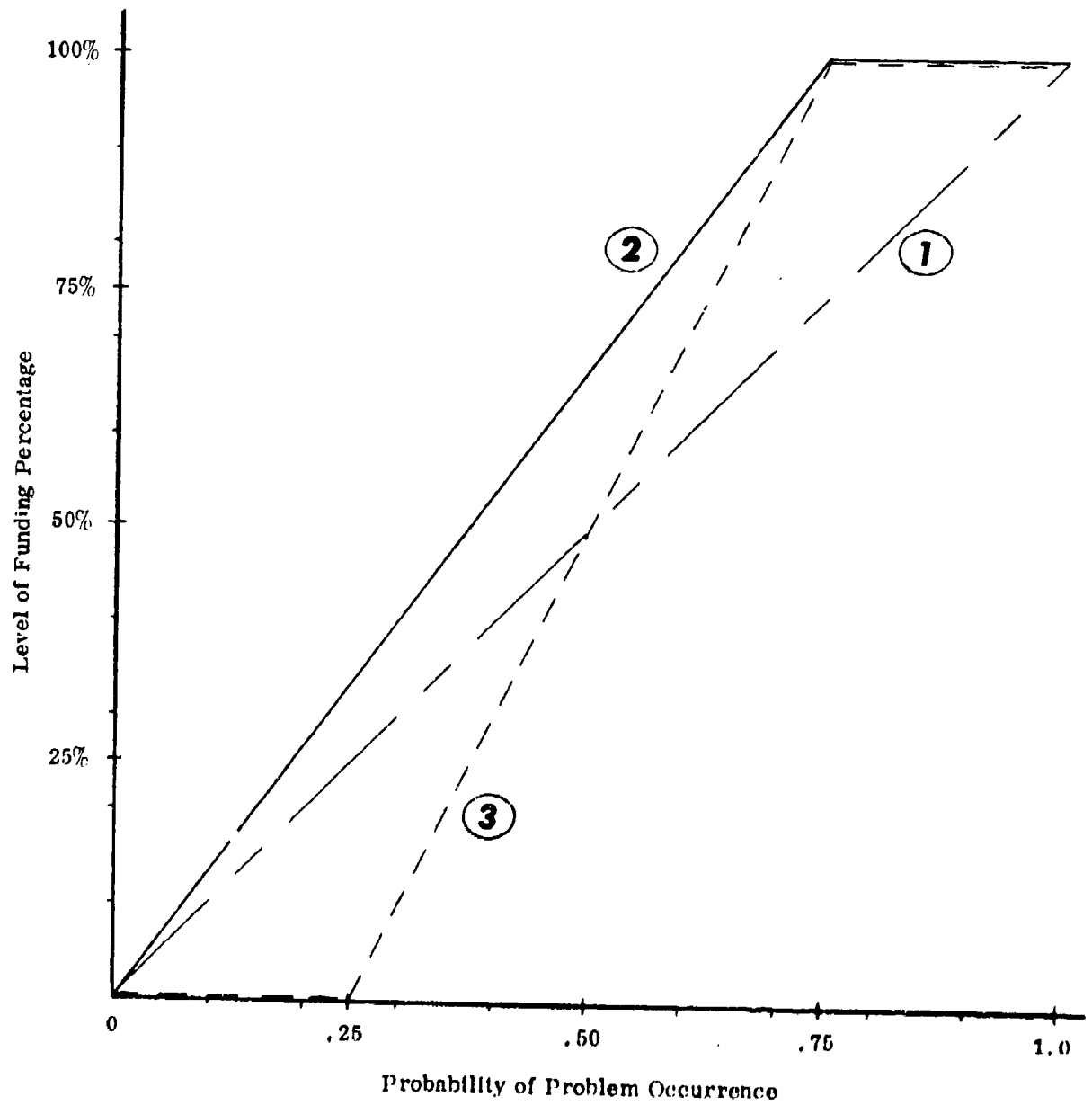
Curve #3 shows an arbitrary but logical decision criterion where there is no funding below .25 probability, proportional funding between .25 and .75, and full funding above .75 probability. For $0 \geq X < .25$, $Y = 0$, for $.25 \geq X \leq .75$, $Y = -50 + 200X$; for $.75 \geq X \leq 100$, $Y = 100$.

8. Determine the total risk capital by adding the AEL's for all elements and milestones.

For Project (Y),

$$\text{Risk Capital (RC)} = \sum_{i=1}^{N} AEL_i$$

$$RC = \$17.46M$$

9. Allocate the risk capital by fiscal year. The objective here is to plan the RC in the fiscal year it will most likely be needed. However, since the RC can be transferred for 1 year, if there is reasonable doubt on the allocation, the money should be placed in the earlier of the two years under consideration. Columns 7 & 8 contain estimates of when the program impacts will occur. The estimates were based on a fixed schedule and we are now interested in when the impacts will probabilistically occur. Without the aid of a computer and network model of interactions, the determination of a comprehensive probabilistic schedule is not possible. However, one can look to the end of each fiscal year and determine if the expenditures may fall in the following year.

The expected schedule slippage for each element can be calculated by multiplying the probability of occurrence P(B), by the schedule impact (asterisk designated, Column 6).

The total expected schedule slippage for the program is,

$$E(l_s) = \sum_{i=1}^{N} P(B_i)(l_{si})$$

$E(l_s)$ = Expected schedule loss for the program

$P(B_i)$ = Probability of a problem occurrence in the ith element

l_{si} = Schedule loss associated with the ith element

For the example Project (Y),

$$E(l_s) = (.60)(2) + (.45)(2) + (.75)(2) + (.70)(3) + (.60)(1) + (.30)(2)$$

$$E(l_s) = 6.9 \text{ months}$$

Note: Element #5 for the engine is omitted since the schedule slippage for the engine does not impact the overall program schedule.

This means on the average Project Y will take 6.9 months longer than planned.

Since the elements are arranged in ascending order according to the calendar date of occurrence, the RC for the 9th element will be needed after the 8th element.

The expected schedule loss through the 8th element is,

$$E(l_s)_8 = (.60)(2) + (.45)(2) + (.75)(2) + (.70)(3) + (.60)(1)$$

$$E(l_s)_8 = 6.3 \text{ months}$$

Therefore, on the average, the impact from element 9 will not occur until 6.3 months later than its date of impact in Column 6. Instead of 10/79, the impact will be 4/80 calendar date. The fiscal year remains FY80. The probabilistic date of impact is obtained by adding the expected slippage to the original date of impact.

All fractional months are rounded down to minimize the impact of errors in the
analysis. See Risk Capital Allocation, Table 4.3, page 54.

ADDITIONAL SAMPLE CALCULATIONS FOR PROBABILISTIC DATE OF IMPACT

Expected schedule loss through the 7th element:

$$E(1_s)_7 = (.60)(2) + (.45)(2) + (.75)(2) + (.70)(3)$$

$$E(1_s)_7 \approx 5.7 \text{ months}$$

Probabilistic date of impact for element 8 = Calendar date of impact for element 8
+ expected schedule loss through the 7th element

$$= 7/79 + 5.8 \text{ months}$$

$$= 12.8/79 \text{ or } \underline{12/79}$$

$$E(1_s)_6 = (.60)(2) + (.45)(2) + (.75)(2)$$

$$E(1_s)_6 \approx 3.6 \text{ months}$$

Probabilistic date of impact of element 7 = 2/79 + 3.6 months = 5.6/79 or $\underline{5/79}$

10. The next step is to review the analysis and determine where good judgement
should alter the mathematically indifferent results. Assuming there is a managerial
exception for a transfer of $1M from FY79 to FY78, the solution to the risk capital
determination and FY allocation is given below.

Total Risk Capital $\underline{\$17.46M}$

FY Allocation

	FY	78	79	80
Risk Tabulation		$2.19M	$11.67M	$3.6M
Project Y Recommendation		$3.19M	$10.67M	$3.6M

Note to Management: Management is encouraged to make exceptions in the mathematical process where judgement dictates. This is usually necessary to "fine tune" study results to realistic management needs. However, the exceptions should be clearly noted.

PROJECT Y
WEAPON SYSTEM RISK ASSESSMENT
TABLE 4.2

Program Elements	Prob. of Occurrence P(A)	Cost Impact to Element/ Milestone TYPE A	Prob. of Occurrence P(B|A)	P(B)	Cost/Schedule Impact to Other Program Elements TYPE B	Date of Impact Calendar Date	Date of Impact FY	Expected Loss	Adjusted Expected Loss
1	2	3	4	5	6	7	8	9	10
Vehicle									
1. Armor	.20	$3.0M	–	–		4/78	78	$ .6M	$ .8M
2. Suspension	.60	$ .4M	1.0	.60	$1M, 2MN*	6/78	78	$ .84M	$1.12M
3. Tracks	.25	$ .8M	–	–	–	6/78	78	$ .2M	$ .27M
4. Power Train	.60	$1.5M	.75	.45	$4M, 2MN*	9/78	78	$2.7M	$3.6M
5. Engine	.20	$ .5M	1.0	.20	$ .5M, .1MN, Engine Qualification	9/78	78	$ .2M	$ .27M
6. Integration	.75	$ .2M	1.0	.75	$2M, 2MN*	11/78	79	$1.65M	$2.2M
Program Milestones									
7. Initiate Acceptance Testing	.70	0.0	1.0	.70	$6M, 3MN*	2/79	79	$4.2M	$5.6M
8. OSD Review	.60	0.0	1.0	.60	$2.5M, 1MN*	7/79	79	$1.5M	$2M
9. DSARC	.30	0.0	1.0	.30	$4M, 2MN*	10/79	80	$1.2M	$1.6M
Totals								$13.09M	$17.46M

*Total Program Schedule Slips

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RISK CAPITAL ALLOCATION
TABLE 4.3

Program Elements 1	Date of Impact Calendar Date 2	Expected Slippage Prior to Given Element (Months) 3	Probabilistic Date of Impact Calendar Date 4	FY 5	AEL 5	6		RISK CAPITAL
Vehicle								
1. Armor	4/78	0.0	4/78	78	$ .8M		F Y 7 8	
2. Suspension	6/78	0.0	6/78	78	$1.12M			$2.19M
3. Tracks	6/78	1.2	7/78	78	$ .27M			
4. Power Train	9/78	1.2	10/78	79	$3.6M			
5. Engine	9/78	1.2	10/78	79	$ .27M		F Y 7 9	$11.67M
6. Integration	11/78	2.1	1/79	79	$2 2M			
Program Milestones								
7. Initiate Acceptance Testing	2/79	3.6	5/79	79	$5.6M		F Y 8 0	
8. OSD Review	7/79	5.7	· 12/79	80	$2M			$3.6M
9. DSARC	10/79	6.3	4/80	80	$1.6M			
					Total			$17.46M

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ANNEX A

TRACE Budget Request

TRACE Budget Request

Introduction: This is an example of the documentation to support an initial TRACE budget request. The following information should be provided:

1. Results

   a. 50/50 TRACE point (applicable to network models only)

   b. Recommended TRACE, risk capital and fiscal year allocations

2. Methodology - brief discussion of methodology with appropriate attachments (e.g. display of network, risk tables, etc.)

3. Cost omissions (Qualitative discussion)

   a. Unknowns - those things that could not be costed since they were not known to exist should be addressed. For example, a project that is significantly advancing "the state of the art" and is early in the development cycle may expect relatively more unknowns to be a factor

   b. Knowns - cost factors that were knowingly omitted from the analysis

4. Significant Assumptions Concerning (Brief listing)

   a. The project

   b. The cost study

   c. Other

5. Pertinent Discussion - addressing the analysis, allocation of monies, logic and significant points or findings

6. Alternatives -addressing only the viable alternatives, if any, and only to the extent necessary to provide essential decision information

   Note to Management: If viable alternatives do not exist or are not under consideration, the alternative section should be omitted with a note to this effect. Under no circumstances should alternatives be generated for the sake of having alternatives.

(EXAMPLE)

Project X TRACE Budget Request

1. Results: TRACE and RISK CAPITAL

	BUDGET	RISK CAPITAL @		RECOMMENDED
		50%	60%	60% (Adjusted)
FY77	$97.7M	$2.04M	$2.07M	$2.07M
FY78	42.7M	6.09M	7.53M	9.53M
FY79	19.3M	3.04M	3.00M	3.
FY80	1.0M	2.15M	3.04M	3.04M
TOTAL	$162.7M	$16.19M	$15.03M	$20.03M

TRACE __$172.25M__

A-5

2. Methodology

The computations pertaining to the risk capital, TRACE, schedule and allocation of risk capital were performed using the network analyzer computer program. Figure 1 represents a portion of the network related only to the missile development. The complete network is comprised of all known activities (Government and Contractor) in the Project X development program. These activities are structured together to capture the integration of the subsystems and the interdependencies of the individual activities. In addition, all major milestones and decision points are included. The major drivers of the milestones can be identified in terms of schedule and cost impact. The model logic and its supportive cost and schedule information were inputs resulting in probabilistic outputs for program cost and schedule and cost. The applied network methodology is consistent with the network methodology discussed in the Army publication," Guide to Total Risk Assessing Cost Estimate (TRACE) and Risk Capital Allocation", dated 31 December 1976.

3. Cost Omissions

a. With respect to unknown occurrences, Project X has significant political implications. Relative to other defense projects there is a higher probability for the project to receive program instructions from higher authorities that will result in a cost impact. In addition, the program schedule is dependent upon timely hardware deliveries from European sources. The project has little control over the European vendors and anticipates schedule and cost problems as a result. The project's history supports this statement.

MISSILE
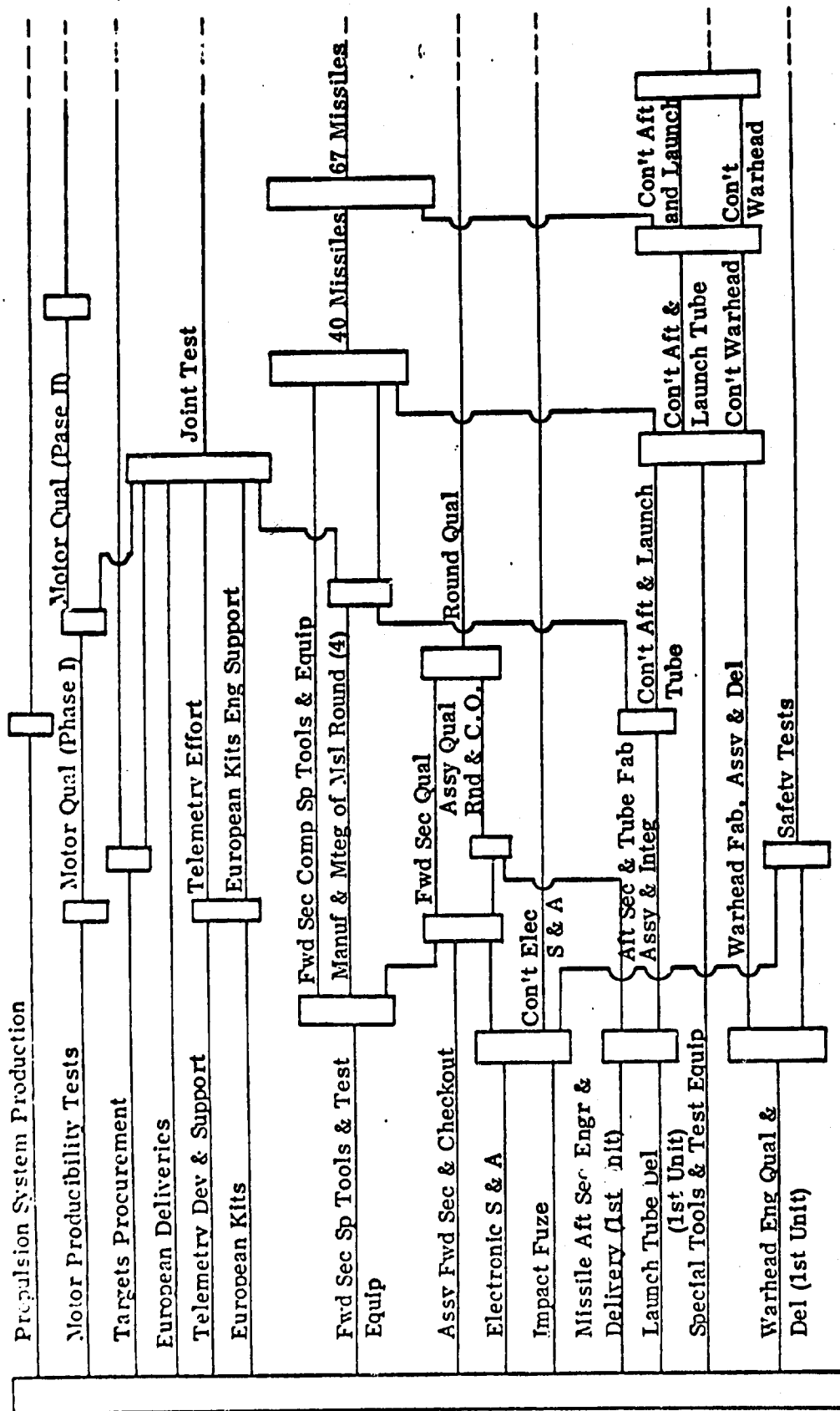
FIGURE 1 - MISSILE SUBSYSTEM NETWORK

b. The project costs as modeled could have been collected in constant dollars and automatically inflated. However, due to the time constraint, the data were collected in the more accessible form of escalated dollars. The expected schedule for the probabilistic model is longer than the schedule associated with the data base. Thus, the TRACE and risk capital output is less than if the monies were appropriately escalated.

4. Significant Assumptions

There are no highly sensitive or peculiar assumptions with the mathematics of the network modeling and data analysis. The most sensitive assumption concerns the management logic dictating the activities that must be completed prior to the OSD decision for production release. The OSD review occurs during a period of high monthly expenditures and the unanticipated delay of this milestone would result in a $2M/month impact to the program.

5. Discussion

Due to the stated cost omissions, Project X recommends using the TRACE value corresponding to the 60th percentile. The effects of the cost omissions make the TRACE risks at the 60th percentile effectively more. How much more is unknown. There is strong argument for using the 70th percentile and recomputing the risk capital at the end of the first fiscal year. However, the Project Office believes the 60th percentile to be a reasonable compromise between the more conservative 70th percentile and the 50th percentile recommended by the DA guidelines.

In addition to using the 60th percentile, an additional $2M in FY81 is recommended to offset the risk associated with the contractor's deferring certain work tasks in FY-0. This situation was discovered after the completion of the network analysis and the constraint required this matter to be handled on an exception basis.

Schedule Distribution for All Activities


```
                                                      35.68   39.36  40.33  40.71  41.33  42.05  42.73  43.41  44.05  44.76  45.43  46.11  46.78  47.46  48.13  48.81  49.48
```

U.S. POLAND TRACE RISK NETWORK

TIME DISTRIBUTION FOR TERMINAL NODE 90
MEAN = 42.32   STANDARD DEVIATION = 2.67

A-6

Cumulative Schedule Distributions for All Activities

A-V

```
+-I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I
38.68  39.36  40.03  40.71  41.38  42.05  42.73  43.41  44.08  44.76  45.43  46.11  46.78  47.46  48.13  48.81  49.48
```

U.S. ROLAND TRACE RISK NETWORK TTF+T

TIME DISTRIBUTION FOR TERMINAL NODE 90
MEAN = 42.22   STANDARD DEVIATION = 2.67

Cost Distribution for All Activities


```
.248   I
       I
.223   I
       I
.198   I
       I
.174   I
       I
.149   I
       I
.124   I
       I
.099   I
       I
.074   I
       I
.050   I
       I
.025   I
       I
0.000  Y +I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I
         157557.75   161453.41   164549.06   167540.37   171540.37   175036.02   178531.67   182027.32   185522.98
            159305.53   162851.24   166296.89   169792.54   173288.19   176783.85   180279.50   183775.15   187270.80
```

COST DISTRIBUTION FOR TERMINAL NODE 93

TRACE RISK NETWORK

MEAN = 163653.95   STANDARD DEVIATION = 6486.55

Cumulative Cost Distribution for All Activities

50/50 TRACE POINT $167.65M

TRACE RISK NETWORK

COST-DISTRIBUTION-FOR-TERMINAL-NODE-90
MEAN = 168653.95   STANDARD-DEVIATION = 6486.55

157557.75 — 161053.41 — 164549.05 — 168044.71 — 171540.37 — 175036.02 — 178531.67 — 182027.32 — 185522.98
155305.58 — 162801.24 — 166296.89 — 169792.54 — 173288.19 — 176783.85 — 180279.50 — 183775.15 — 187270.80

6. Alternatives

There are no major program alternatives. However, there is a management
option in the testing program that may generate significant cost savings. The option
is to build a second test site for parallel testing during PQT-G/C. This will eliminate
the problem of range availability due to sequential testing of the Joint Test and
PQT-G/C. The Joint Test may slip 6 months or more due to delayed European
hardware deliveries. The cost to build the second test site is $.8M and expected
savings are $10M. The minimum savings are estimated at $4M. This information
was recently generated through the project's network model and is presently being
verified. The decision will be made within 30 days to allow the necessary lead time.
With a favorable decision FY81 risk capital funds will be used for the project.

ANNEX B

Fiscal Year Risk Capital Request and Justification

MESSAGE

Date x/x/xx

TO: DAMA-PPR

FROM: PROJECT X

SUBJECT: RISK CAPITAL REQUEST

1. Request risk capital in amount of $2,200,000.00 be released to Project X
    (account #   ) on ___(date)___

2. These monies will be used for the establishment of a second test site in order
    to reduce the calendar time for the testing program.

cf: DRCDE-PC

Note to Management: A request for risk capital must provide the amount
        needed, the date needed and the basic use planned for the money. The
        responsibility for the expenditure of these monies is the project manager's,
        therefore an elaborate justification is not needed.

TO: DRCDE-PC

FROM: PROJECT X

SUBJECT: RISK CAPITAL JUSTIFICATION

1. Reference message dated _____, subject Risk Capital Request from

    Project X to DAMA-PPR.

2. The justification of the referenced request is given below.

3. The Project network analysis of the cost/schedule revealed that the European

    delivery of the fire unit for the joint test is the most sensitive schedule element.

    This is due to the current test range availability which dictates sequential

    joint testing followed by government/contractor tests.

4. A study was made to determine which portions of the testing program could be

    performed in parallel rather than in sequence and at the same time maintain the

    objectives of design validation and data accumulation for a production decision.

    From this study a test schedule, with parallel testing as appropriate, was

    developed and included in a network analysis of the entire program. The direct

    test costs will not be changed by testing in parallel; however, the indirect costs

    should be reduced because of the shorter time duration.

5. Results of the analysis showed an expected savings of at least $4M in total program

    costs and 3 months in the schedule. The most likely savings were found to be

    $7M and 5 months. These results were obtained by using the TRACE network

    model for Project X which has been updated to reflect the current program.

    Comparisons were made of the output data for the current program with sequential

    testing and the current program with parallel testing.

6. In order to gain these costs and schedule benefits it is necessary to build

   a second test site. Funds in the amount of $2.2M were released from the

   FY77 Risk Capital to the Project Office for that objective.

7. Backup data for this justification and the study of Project X Test Program are

   available on request for your office.

   Note to Management: The risk capital justification should be concise and only
              to the depth necessary to explain how the funds are being spent
              and why.

ANNEX C

Cost/Schedule Input Data for Project X
Network Analysis

U.S. ROLAND TRACE NETWORK INPUT DATA

Act #	Activity Description & Relationships	Cost ($K) a-fixed b-variable	Schedule	Node From	Node To
1	Telemetry Dev & Support	a=0 b=31.3-32.9-36.2	t=2	N01	N02
2	Telemetry Effort	a=242. b=31.3-32.9-36.2	t=11	N02	N03
3	European Kits	a=0 b=36.5	t=2	N01	N02
4	European Kits Eng Support	a=0 b=0	t=Cont. to Joint Test	N02	N03
5	Admin Config Mgt Sys Support	a=216. b=56.3-62.5-68.7	t=Cont. to DSARC	N01	N75
6	Engineering Support	a=64.8 b=39.9-44.9-49.9	t=Cont. to DSARC	N01	N75
7	Fwd Sec SP Tools & Test Equip (Implementation)	a=59.1 b=81-90-99	t=2	N01	N05
8	Impact Fuze	a=115.9 b=0	t=5	N01	N10
9	Electronic S & A	a=51. b=218.	t=5	N01	N10
10	Assy Fwd Sec & Checkout	a=40. b=55.6-61.6-67.6	t=4	N01	N11
11	Con't Elec S & A	a=0 b=21.6	t=16	N10	N09

Act #	Activity Description & Relationships	Cost ($K) a-fixed b-variable	Schedule	Node From	Node To
12	S			N10	N25
13	S			N10	N11
14	Manuf & Integ of MSL Rnd (4)	a=574.9 b=158.1-166.4-191.4	t=10.5	N05	N06
214	S			N05	N11
15	Fwd Sec Comp SP Tools & Equip	a=0 b=81-90-99	t=10	N05	N07
16	S			N06	N03
17	Manuf & Integ Msl Rnd (15)	a=0 b=158.1-166.4-191.4	t=1.5	N06	N07
18	Fwd Sec Qual	a=1.4 b=15.9-16.75-19.3	t=4	N11	N13
19	S			N11	N12
201	European Deliveries	a=0 b=0	t=11. 13. 19.	N01	N03
202	Targets Procurement	a=5550. b=0	t=12	N01	N51
203	S			N51	N70
204	S			N51	N03

Act #	Activity Description & Relationships	Cost ($K) a-fixed b-variable	Schedule	Node From	Node To
20	Assy Qual Rnd & C.O.	a=0 b=0	t=2	N12	N13
21	Manuf & Integ Msl Rnd (40)	a=0 b=158.1-166.4-191.4	t=2	N07	N08
22	S			N07	N70
23	Round Qual	a=1.4 b=15.9-16.75=19.3	t=4	N13	N60
24	Manuf & Integ Msl Rnd (67)	a=0 b=158.1-166.4-191.4	t=5	N08	N09
25	S			N08	N73
26	Part "A" Testing Con't	a=1593.	t=4	N52	N71
221	Joint Test	a=2183 2933 3683 b=0	t=4	N03	N52
27	S			N09	N75
28	Motor Producibility Tests	a=354. b=33.3	t=5	N01	N14
31	Motor Qual (Phase I)	a=0 b=33.3	t=5.5	N14	N16
32	S			N16	N03

Act #	Activity Description & Relationships	Cost ($K) a-fixed b-variable	Schedule	Node From	Node To
33	Motor Qual (Phase II)	a=0 b=29.5	t=2.5	N16	N17
34	S		t=18	N17	N70
35	Propulsion Sys Production	a=239. 244 266 b=61.5-62.8-68.5		N01	N18
36	S			N18	N73
37	Msl Aft Sec Engr & Delivery (1st Unit)	a=573-585-614 b=149-152.2-160	t=6	N01	N19
38	Launch Tube Del. (1st Unit)	a=4.7-5.0-5.6 b=38.5-40-45.4	t=6	N01	N19
39	Special Tools & Test Equip	a=129.7-131.0-137.5 b=45.2-45.7-48.0	t=13	N01	N21
40	Warhead Eng Qual & Del (1st Unit)	a=270-282-313 b=22.3-23.2-25.8	t=6	N01	N24
41	S			N19	N12
42	Aft Sec & Tube Fab Assy & Integ (4 units for Joint Tests)	a=0 b=206.4-212.8-232.0	t=6	N19	N20
43	S			N20	N06

Act #	Activity Description & Relationships	Cost ($K) a-fixed b-variable	Schedule	Node From	Node To
44	Con't Aft & Launch Tube (15)	a=0 b=119.7-123.4=134.5	t=1.5	N20	N21
45	Warhead Fab Assy & Del (75)	a=0 b=22.3-23.2-25.8	t=6	N24	N21
46	S			N24	N25
47	Safety Tests	a=0 h=0	t=6	N25	N70
247	S			N21	N07
48	Con't Aft & Launch Tube (59)	a=0 b=67.2-69.3-75.5	t=2	N21	N22
49	Con't Warhead (26)	a=0 b=0	t=3	N21	N22
50	S			N22	N08
51	Con't Aft & Launch (52)	a=0 b=67.2-69.3-75.5	t=4	N22	N23
52	Con't Warhead (12)	a=0 b=0	t=1	N22	N23
53	S			N23	N09
54	Special Tools & Test Equip	a=96.-100.-120. b=204.5-213.0-255.6	t=Con't thru Integ & Test of F.U.	N01	N32

ACT	Activity Description & Relationships	Cost ($K) a-fixed b-variable	Schedule	Node From	Node To
55	Launch & Guidance Control Fab Assy & C.O.	a=314.0-349.0-418.8 b=56.3-62.5-75.0	t=8.2 9.2	N01	N26
56	Aux Equip Fab Assy & C.O.	a=222.8-237.0-286.8 b=83.1-88.4-107.0	t=8.2 9.2	N01	N27
57	Cabin Fab Assy & C.O.	a=244.7-266.0-305.9 b=206.8-224.8=258.5	t=11	N01	N28
58	Turret Fab Assy & C.O.	a=354.0-389.0-462.9 b=243.0-267.0-317.7	t=11	N01	N29
59	Communication Equip (GPE)	a=2.0-2.0-2.1 b=7.8-7.9-8.0	t=8	N01	N30
60	Fire Unit Integ Support	a=489.9-505.0-545.4 b=216.7-223.4-241.3	t=10	N01	N30
61	Con't Launch & Guid Control	a=6.3-7.0-8.4 b=62.0-68.9-82.7	t=3	N26	N31
62	1st Del Launch & Guid	a=0 b=0	t=0	N26	N30
63	Con't Aux Equip	a=0 b=91.4-97.2-117.6	t=3	N27	N31
64	1st Del Aux Equip	a=0 b=0	t=0	N27	N30
65	Con't Cabin	a=9.2-10.0-11.5 b=116.4-126.5-145.5	t=3	N28	N31

Act #	Activity Description & Relationships	Cost ($K) a-fixed b-variable	Schedule	Node From	Node To
66	1st Del Cabin	a=0 b=0	t=0	N28	N30
67	Con't Turret	a=0 b=93.8-103.1-122.7	t=3	N29	N31
68	1st Del Turret	a=0 b=0	t=0	N29	N30
69	F. U. Integ & Test Units 1 & 2	a=103.8-107.0-115.6 b=172.0-177.4-191.6	t=3	N30	N31
70	Complete F.U. Integ & Test (3 & 4)	a=5.3-5.5-6.0 b=118.5-122.2-132.0	t=2	N31	N32
71	Deliver Units 1 & 2	a=0 b=0	t=0	N31	N70
72	Integ Support	a=0 b=45.5-46.9-50.7	t=9	N32	N33
73	Training & Road Test	a=0 b=0	t=3	N32	N74
74	Con't Integ Support	a=0 b=10.2-10.5-11.3	t=Con't to Termination	N33	N74
76	PEP (BAC)	a=0 b=5.45	t=Con't to OSD Review	N30	N74

Act #	Activity Description & Relationships	Cost ($K) a-fixed b-variable	Schedule	Node From	Node To
77	Search Radar Eng Manuf & Test to 1st Delivery	a=329.1-346.5-381.1 b=233-245-270	t=9-10-11	N01	N35
78	Search Radar 1st Unit Delivery	a=0 b=0	t=0	N35	N30
79	Search Radar Con't Eng Manuf & Test	a=0 b=233-245-270	t=3-5	N35	N32
80	PEP (SEARCH)	a=0 b=65.7-68.6-74.5	t=9	N35	N74
81	IFF Procurement	a=77.3 b=0	t=4	N01	N30
82	Track Radar Eng Manuf & Test	a=375-375-405 b=432-528	t=9-10-13	N01	N36
83	1st Unit (TRACK)	a=0 b=0	t=0	N36	N30
84	Con't Eng Manuf & Test (TRACK)	a=0 b=218-266	t=4-5-7	N36	N32
85	PEP (TRACK)	a=0 b=35.6-35.6-46.3	t=9	N36	N74
86	Electro Optical Eng Manuf & Test	a=0 b=150.	t=7.0-7.5-8.0	N01	N37

Act #	Activity Description & Relationships	Cost ($K) a-fixed	Schedule	Node From	Node To
87	1st Unit (Electro Optical)	a=0 b=0	t=0	N37	N30
88	Con't Eng Manuf & Test (Electro Optical)	a=0 b=110.	t=7.0-7.5-8.0	N37	N32
89	Support Integ (Electro Optical)	a=0 b=6	t=con't to Completion of F.U. Integ	N37	N32
90	PEP (Electro-Optical)	a=0 b-55	t=0	N37	N74
91	OMTS Clear Weather Procurement Delivery & C.O. (No. 1 Set)	a=758 b=0	t=8-10-12	N01	N31
92	OMTS Proc Del & CO Clear Weather (No. 2 Set)	a=848. b=17.3-18.2-27.3	t=12-15	N01	N70
93	OMTS Track Radar	a=1000. b=0	t=26	N01	N90
94	OMTS Operator Proficiency Trainer No. 1	a=1449. b=0	t=10	N01	N70
95	OMTS Operator Proficiency Trainer No. 2	a=1449. b=21.0-22.9-27.3	t=13	N01	N74
96	ILS Support FMTS	a=0 b=79.3	t=con't to End of Unit 1 Shelter Install	N01	N42

Act #	Activity Description & Relationships	Cost ($K) a-fixed b-variable	Schedule	Node From	Node To
97	System Design FMTS	a=0 b=359.8	t=6-8	N01	N38
98	Fab & Assy (Phase I) FMTS	a=1322.5 b=233.1	t=10-12	N38	N40
99	S	a=0 b=0	t=3	N01	N39
100	Hdw Design FMTS	a=0 b=259	t=3	N39	N40
101	Integ & C.O. 1st Unit FMTS	a=0 b=74	t=5-7	N40	N41
102	Shelter Installation 1st Unit FMTS	a=0 b=74	t=1	N41	N42
104	Con't Shelter Instal. FMTS	a=0 b=74	t=2	N42	N44
105	Integ & C.O. Unit 2 FMTS	a=0 b=74	t=2	N42	N43
106	Environmental Tests (FMTS)	a=0 b=74	t=4	N43	N44
107	S			N44	N79
108	ILS (HAC) Includes LSAR Mag Tape $466K Training Opt @ $850K	a=0 b=194.2-230.2	t=17-19-21	N1	N74

Act.	Activity Description & Relationships	Cost ($K) a-fixed b-variable	Schedule	Node From	Node To
109	S			N01	N45
110	PROTO Fab Assy & C.O. (2) + Queen (vehicle)	a=1032.1-1147.1-1147.1	t=11	N45	N46
111	Prog Mgt Eng Pubs Tech Data & Test Support (vehicle)	a=0 b=20.5-22.8-22.8	t=32	N45	N49
112	Gov't Support (ARMCOM) (vehicle)	a=0 b=7.62-8.42-8.42	t=32	N45	N49
113	Deliver 2 Units (vehicle)	a=0 b=0	t=0	N46	N31
114	Fab Assy & C.O. (vehicle)	a=207-230-230 b=0	t=3	N46	N47
115	Deliver 2 Units (vehicle)	a=0 b=0	t=0	N47	N32
116	S			N47	N49
117	Manuals Provisioning Eng Vehicle	a=0 b=21.4-23.8-23.8	t=21	N45	N49
118	S			N49	N90
119	Prog Mgt (HAC/BAC)	a=0 b=413.3-432.2-505.5	t=Con't to OSD Review	N01	N74

Act #	Activity Description & Relationships	Cost ($K) a-fixed b-variable	Schedule	Node From	Node To
120	Sys Eng & Test Support HAC/BAC	a=395.7-421.0-505.2 b=555.6-601.2-698.0	t=Con't to OSD Review	N01	N74
121	DATA (BAC)	a=0 b=131.3-136.8-164.2	t=Con't to OSD Review	N01	N74
122	Spares	a=220.5-245.0-269.5 b=53.2-59.1-65.0	t=½	N01	N50
123	Spares Con't	a=63.9-71.0-78.1 b=19.7-21.9-24.1	t=Con't to OSD Review	N50	N74
124	PQT Part A BAC	a=0 b=0	t=2	N70	N52
125	Problem Fix 45% Probability of Occurrence	a=0 b=0	t=3-4.5-6	N71	N72
126	Success (Part A Test) 55% Probability of Occurrence	a=0 b=0	t=0	N71	N72
127	S		t=2	N70	N81
128	Contr/M.1 Training	a=0 b=198-208	t=3	N81	N74
129	S			N72	N73

Act.	Activity Description Y Relationships	Cost ($K) a-fixed b-variable	Schedule	Node From	Node To
130	S			N72	N74
131	Test Con't	a=0	t=4-4-7	N73	N75
132	BAC Test Support	a=88.8-91.5-109.8 b=119.4-123.1-147.7	t=Con't to DSARC III	N73	N75
133	Complete Tests	a=0 b=0	t=13	N75	N90
134	BAC TEST Support & System Engr	a=0 b=119.4-123.1-147.7	t=Con't to Termination	N75	N90
135	DSARC III	a=0 b=0	t=1	N75	N77
137	OSD Review	a=0 b=0	t=1	N74	N76
138	LLIP & IPF	a=0 b=0	t=0	N76	N78
139	Production	a=0 b=0	t=0	N78	N90
140	Prog Mgt (BAC/HAC)	a=0 b=32.5-41.8-62.2	t=Con't to Termination	N74	N90

Act #	Activity Description & Relationships	Cost($K) a-fixed b-variable	Schedule	Node From	Node To
141	Sys Engr & Test Support (HAC)		t=Con't to Termination	N74	N90
142	ILS	a=28. b=0	t=0	N74	N90
143	M DEMO	a=0 b=34.5-36.2	t=3.0-3.5	N74	N79
144	Contr/Mil Training	a=0 b=0	t=3.5	N79	N80
145	Mil Training	a=0 b=0	t=Con't to Termination	N80	N90
146	Gov't Management & Administration	a=3643 b=991.25-1049.75-1096.30	t=Con't to OSD Review	N01	N74
147	Gov't Management & Administration	a=0 b=422.-473.-548	t=Con't to Termination	N74	N90
148	PDEP's Full Up Final Copy (Preliminary Draft Engr Plan)	a=0 b=178.3	t=7	N79	N90

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